TECHNICAL APPENDIX E: AQUATIC ANIMALS, VEGETATION, AND WILDLIFE

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List of Abbreviations and Acronyms

Aquarium	Seattle Aquarium
BMP	Best Management Practice
CSO	combined sewer overflow
DIDSON	Dual-Frequency Identification Sonar
Ecology	Washington State Department of Ecology
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
Magnuson-Stevens Act	Magnuson-Stevens Fishery Conservation Act
mg/l	milligrams per liter
MLLW	mean lower low water
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
PAHs	polycyclic aromatic hydrocarbons
Parks	Seattle Parks and Recreation
PHS	Priority Habitat and Species
SPCC	Spill Prevention, Containment, and Control
SQS	Sediment Quality Standards
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife

INTRODUCTION

This technical appendix provides the available information used to evaluate the potential effects to aquatic animals, vegetation, and birds that may be associated with the master planning alternatives being proposed by Seattle Parks and Recreation (Parks) for the removal and possible reconstruction of Piers 62/63 and improvements to Waterfront Park. The outcome of the Environmental Impact Statement (EIS) will be the adoption of a Central Waterfront Master Parks Plan, based on the chosen preferred alternative, for the Seattle Central Waterfront park spaces west of Alaskan Way from Waterfront Park to Piers 62/63 and including the Seattle Aquarium (Aquarium).

Five alternatives are under consideration for the Central Waterfront Master Parks Plan. Following is a description of each alternative. Graphic depictions of these alternatives are included in Figures 2 through 5 at the end of this document. Cross-sections of each type of habitat enhancement referred to in the alternatives descriptions are shown in Figures 1a and 1b.

- **No Action/No Build Alternative** – Parks would take no action to maintain, improve, or rebuild Waterfront Park and Piers 62/63. Continued deterioration in the No Action/No Build Alternative would eventually necessitate removal of Piers 62/63. No habitat enhancements would be constructed.
- **Rebuild/Preservation Alternative** – In Phase 1 of construction, Piers 62/63 would be rebuilt as a similar structure in the same location but set away from the shoreline to allow direct light to penetrate through the water column along the seawall (Figure 2). Habitat would be enhanced along the shoreline from the northern edge of the Aquarium to the southern edge of the submerged Virginia Street right-of-way. The habitat enhancement would be the creation of a gently sloping habitat bench at approximately the mean lower low water (MLLW) elevation. Waterfront Park would be preserved with various near-term improvements. It could be replaced with a habitat enhancement associated with any future

Aquarium improvements. The habitat enhancement would be a backshore beach with a gently sloping habitat bench at approximately MLLW. This would include a naturally sloping foreshore and riparian vegetation. This beach would be accessible by people.

- **Aqua Link Alternative** – Piers 62/63 would be removed in Phase 1 and rebuilt as a smaller structure closer to the Aquarium (Figure 3). Two types of habitat enhancements would be built along the shoreline from the northern edge of the Aquarium to the southern edge of the submerged Virginia Street right-of-way. Along most of the shoreline, the habitat enhancement would be a backshore beach with a gently sloping habitat bench at approximately MLLW. This would include a naturally sloping foreshore and riparian vegetation. This beach would be accessible by people. Along the shoreline section closest to the Aquarium, a foreshore beach with a gently sloping habitat bench at approximately MLLW would be constructed.

  In Phase 2 of construction, Waterfront Park and the northern portion of the Aquarium would be demolished as part of the Aquarium's expansion and a new deck connecting the offshore ends of Pier 57 and the Aquarium would be built. A pier-mounted wave attenuator would be attached to the connecting pier deck in order to reduce wave energy along the shoreline. A foreshore beach with a gently sloping habitat bench at approximately MLLW would be constructed. Along both sections of foreshore beach with habitat bench created by this alternative, the riprap positioned at either end of the beach to maintain its shape would include grouted basins of various sizes that form tidepools.

- **Connector Alternative** – In Phase 1 of construction, Piers 62/63 would be removed and a similar structure would be built in the same location but set away from the shoreline to allow direct light to penetrate through the water column along the seawall (Figure 4). This initial construction phase would also build a slender footbridge and deck connecting to the offshore end of the Aquarium. Two types of habitat enhancements would be built along the shoreline from the northern edge of the Aquarium to the southern edge of the submerged Virginia Street right-of-way. Inshore of the new pier, a foreshore beach with a gently sloping habitat bench at approximately MLLW would be constructed. The offshore margin of the habitat bench would be the inshore edge of the new pier. Along the remainder of this enhancement area, a backshore beach with a gently sloping habitat bench at approximately MLLW would be constructed. This would include a naturally sloping foreshore and riparian vegetation. This beach would be accessible by people.

In Phase 2 of construction, Waterfront Park and the northern portion of the Aquarium would be demolished as part of the Aquarium expansion and a pedestrian deck would be built along the northern edge of the Aquarium. Inshore of this deck and along the former Waterfront Park, a foreshore beach with a gently sloping habitat bench at approximately MLLW would be constructed. This area would include a rock wave attenuator located just offshore of the habitat bench. The rock wave attenuator would extend from approximately -2 feet to +4 feet MLLW and be designed to provide low energy habitat for juvenile salmon. Along all sections of foreshore beach with habitat bench created by this alternative, the riprap positioned at either end of the beach to maintain its shape would include grouted basins of various sizes that form tidepools.

- **Multi-Purpose Pier Alternative** – In Phase 1 of construction, Piers 62/63 would be removed and rebuilt as a large open platform abutting an expanded Aquarium and set away from the shoreline (Figure 5). In the northern end of the project area, a foreshore beach with a gently sloping habitat bench at approximately MLLW would be constructed. Inshore of the new pier and extending to the Aquarium, a gently sloping habitat bench at the MLLW elevation would be constructed.

  In Phase 2 of construction, Waterfront Park and the northern portion of the Aquarium would be demolished as part of the Aquarium's expansion. Along the former Waterfront Park, a backshore beach with a gently sloping habitat bench at approximately MLLW would be constructed. This would include a naturally sloping foreshore and riparian vegetation. This beach would be accessible by people.

INFORMATION SOURCES

Existing information on aquatic animals, vegetation, and birds in the project vicinity was collected by reviewing available literature, performing internet searches, and communicating with biologists familiar with the project area. A Feasibility Study conducted to develop and evaluate the feasibility of the alternatives included coordination with representatives from various federal, state, and local agencies (Makers 2005).

The following sources of information were identified:

- Seattle Central Waterfront Park Planning Feasibility Study (Makers 2005)
- Fisheries, Wildlife, and Habitat Discipline Report for the SR 99 Alaskan Way Viaduct and Seawall Replacement Project Draft EIS (Parametrix 2004)
- Seattle Seawall Underwater Survey (Weitkamp 2003)
- Draft Seattle's Central Waterfront Concept Plan (Seattle DPD 2006)
- Seattle Aquarium Master Plan for Expansion Draft Programmatic EIS (TRA Planning Services and Vicki Morris Consulting 1995)
- Aquatic Environment Technical Report for the Seattle Aquarium Master Plan for Expansion (Taylor Associates 1995)
- Biological Assessment for the City of Seattle – Seattle Aquarium, Pier 59 Pile Superstructure Maintenance (Ridolfi Inc 2004)
- Biological Opinion for City of Seattle Aquarium Pier 59 Pile Superstructure Maintenance (NMFS and USFWS 2005)
- Elliott Bay Waterfront Recontamination Study (Ecology 1995)
- SEDQUAL Sediment Quality Information System (Ecology 2004)

Site-specific information was also provided by Aquarium staff. Jeff Christiansen, a biologist with the Aquarium, provided observations of existing substrate, debris, and aquatic resources that he made in the project area through many years of diving at the site. C.J. Casson provided a list of species that Aquarium divers collected at Piers 59/60 between 2000 and 2004.

AFFECTED ENVIRONMENT

Project Area

The project area extends from the southerly boundary of the existing Waterfront Park in the City of Seattle to just beyond the northerly boundary of Piers 62/63. The offshore margin of the project area is the Outer Harbor Line and the inshore margin is the western border of the Alaskan Way right-of-way. The project area extends along approximately 1,200 linear feet of the waterfront.

The Aquarium is located on Pier 59 in the project area. The conceptual configuration of the Aquarium as described in the Central Waterfront Master Plan (adopted in 1997 and amended in 2004) was included as an existing condition in the project area for all alternatives except for the No Action/No Build Alternative.

Existing Conditions

The project area is situated within the heavily urbanized downtown Seattle waterfront. The project area is located in the middle of a 1.5-mile-long seawall along the Seattle waterfront. The seawall in the project area is a vertical concrete wall with a buttress of large angular rock (riprap). The project area shoreline faces due west. This area can be exposed to high energy conditions during storms; its location within Elliott Bay limits the project area's exposure to storm waves with a long fetch beyond the bay. The longest fetch to the project area is from the northwest; however, winds do not typically blow from that direction. The meteorological conditions in Puget Sound typically result in the strongest storms occurring during the winter with northerly winds. As a result, the project area is protected from the highest wind and wave energy by the Duwamish Head and Alki Point, which form the southwest margin of Elliott Bay.

Like much of the downtown Seattle waterfront, the project area has large overwater structures extending offshore to the Outer Harbor Line (Figure 6). In the southern third of the project area, Waterfront Park extends over the water between Pier 57 and the Aquarium in an arc that is widest (extending approximately 200 feet offshore from the seawall) next to the adjacent piers and most narrow (extending approximately 20 feet offshore from the seawall) at the midpoint between piers. The Aquarium and Piers 62/63 extend offshore more than 400 feet to the Outer Harbor Line.

Bathymetry

Bathymetry in the project area displays an undulating pattern along the seawall, owing to the history of filling for construction of the piers and dredging adjacent to piers. In areas where slips were constructed, berths were dredged for ship docking and the resulting material was piled in under-pier locations (Taylor Associates 1995).

The base of the seawall and rock buttress are underwater during all tides, except a few of the lowest tides of the year. In this way, there is no intertidal beach in the project area. In the 10.4 acre project area, 9.1 acres are deeper than -10 feet MLLW. Table 1 summarizes the existing elevations of habitat relative to overwater structures in the project area. Existing bottom elevations range from approximately +4 feet MLLW to -70 feet MLLW. Offshore from the project area, water depths continue to get deeper. Landward, the vertical seawall along the shoreline forms a clear transition to the upland area.

Table 1

Summary of Existing Habitat Elevations Related to Overwater Structures

Elevation Range	Not Under Pier (acres)	Under Pier (acres)
Supratidal (above +12 feet MLLW)	0.0	0.0
Intertidal (+12 to -4 feet MLLW)	0.0	0.2
Shallow subtidal (-4 to -10 feet MLLW	0.2	0.8
Deep subtidal (below -10 feet MLLW)	5.2	3.9
Total	5.5	4.9

Substrate and Anthropogenic Debris

The dominant substrate of the project area is sand and silt. Table 2 summarizes the substrate characteristics of the project area.

*Table 2. Substrate Characteristics of the Project Area**

Segment	Existing Characteristics
Pier 58 to Waterfront Park	Vertical concrete bulkhead with riprap toe, wood pile-supported pier; sand/silt substrate
Aquarium	Vertical concrete bulkhead with riprap toe, wood and steel pile-supported pier; sand/silt substrate
Aquarium to Piers 62/63	Vertical concrete bulkhead with riprap toe, wood pile-supported pier; sand/silt substrate except rubble pile area at Pier 61
Piera 62/63	Wood deck over shoreline approximately 300 feet wide; vertical concrete bulkhead with riprap toe to 4 to 6 feet MLLW between piers and 2 to 3 feet under piers

* This table modified from Parametrix 2004.

Diver observations of the project vicinity describe the presence of anthropogenic debris scattered throughout the project area (Christiansen 2006) (see Figure 6). Until being demolished in the early 1970s, Pier 61 was situated just south of Pier 62/63. Presently, a pile of concrete rubble covers almost the same footprint as Pier 61 previously had. The concrete rubble is comprised of large slabs with an approximate average size of 6 feet in diameter.

The open areas between Pier 57 and the Aquarium and between the Aquarium and Piers 62/63 have numerous scattered derelict piles lying horizontal on the seafloor. Three large structures, one immediately offshore of Piers 62/63 and two adjacent to Pier 57, are present. These structures are large pieces of debris comprised of steel, wood, and/or concrete that rise several feet off the bottom. Smaller piles of rock, concrete, and soda pop cans occur adjacent to and under the Aquarium. Small assorted anthropogenic debris that is thrown into the water occurs along the margin of all piers and sidewalks in the project area.

Sediment Chemistry

Limited information is available on sediment chemistry in the project area. Washington State Department of Ecology (Ecology) (1995) compiled available data on sediment chemistry along the Seattle waterfront. The only existing surface sediment data in the immediate vicinity of the project area (two stations in the project area and three stations at or beyond the Outer Harbor Line limit of the project area) were from the 1980s. Concentrations of mercury, low molecular weight polycyclic aromatic hydrocarbons (PAHs), and high molecular weight PAHs exceeded Ecology's Sediment Quality Standards (SQS) (Ecology 1995). Ecology (1995) conducted additional investigation of the chemistry of material settling out from the water column and landing in the project area. This investigation detected mercury, bis(2-ethylhexyl)phthalate, pentachlorophenol, benzoic acid, and benzyl alcohol in excess of SQS.

The Ecology (1995) study determined that point sources, such as combined sewer overflow (CSO) outfalls, were "relatively insignificant source(s) of contaminants" to the Seattle waterfront. Instead, Ecology determined that non-point sources, such as small fuel spills, discharges of oily water from vessels, and creosote-treated piles and bulkheads, particularly those in disrepair and potentially decomposing, may affect sediment chemistry along the waterfront.

Freshwater Inputs

No natural streams flow into the project area or Seattle's downtown waterfront. Freshwater discharges from storms are collected and either discharged through storm drains or run through a combined sewer system. One storm drain, the Pine Street storm drain, empties into the project area. This storm drain is located at the southern margin of Piers 62/63. The University Street storm drain and CSO discharge south of the project area at the southern margin of Pier 57. The Pine Street and University Street storm drains divert flow to the combined sewer system during storms smaller than the 1-year storm event and therefore discharge no flow during smaller storms (Ecology 1995). The storm drains and CSO are estimated to introduce low levels of total suspended solids, mercury, and PAHs (Ecology 1995), although low levels of other contaminants may be present. The Ecology (1995) study determined that point sources, such as those entering in or near the project area, were "relatively insignificant source(s) of contaminants" to the Seattle waterfront.

One National Pollutant Discharge Elimination System (NPDES) waste discharge outfall occurs in the project area. The Seattle Steam Company has a NPDES permit (WA-0000150-3, expiration June 15, 2009) to discharge at the southern margin of Waterfront Park where it connects to Pier 57. The NPDES permit allows for up to 50,000 gallons per day of water discharge containing a daily maximum of 10 milligrams per liter (mg/l) of oil and grease. This discharge is wastewater from their ion exchange water treatment system and stormwater (Ecology 1995). The ion exchange system removes hardness from City of Seattle tap water to reduce scale in their boilers. The Ecology (1995) study determined that point sources, such as the CSO and NPDES outfall entering in or near the project area, were "relatively insignificant source(s) of contaminants" to the Seattle waterfront.

Biological Resources

Many groups of biota use the shoreline and aquatic habitats in the project area. To support the goals of the EIS and in consultation with resource agencies, this report highlights those biota with special consideration under the Endangered Species Act (ESA) and under other legislation such as the Magnuson-Stevens Fishery Conservation Act (Magnuson-Stevens Act). The following sections summarize the status and use of the project area by fish, marine invertebrates, marine mammals, and birds.

Fish

Elliott Bay supports a rich community of resident and transient fish species, including several species and stocks of anadromous salmonids. Resident fish species commonly observed in the shoreline area along the seawall include surfperch, bay pipefish, shiner perch, sculpin, greenling, various flatfishes, and a limited number of lingcod (Parametrix 2004). Elliott Bay is a migratory route for large numbers of anadromous salmonids originating from the Green/Duwamish River Watershed, which flows into the bay (City of Seattle 2003). Salmonids originating in other basins (e.g., Lake Washington/Cedar River, Puyallup River, and Snohomish River) may also migrate into Elliott Bay and through the project area (Brennan et al. 2004).

Juvenile salmonids typically rear and migrate through the Seattle waterfront during spring and early summer. Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) are present in Elliott Bay as early as January (Nelson et al. 2004) and are in the marine nearshore as late as October (Brennan et al. 2004), although the residence time of individual fish is not expected to be the entire time period. Juvenile salmon are commonly present during the spring and early summer in the surface waters near the seawall. Data from Ruggerone and Volk (2004) suggest that juvenile Chinook migrate from the Duwamish estuary to Piers 90/91 in northern Elliott Bay in approximately 4 days. Juvenile coho (*O. kisutch*) are generally present in mid-February to mid-June with some numbers remaining until October (Warner and Fritz 1995; Brennan et al. 2004). Little is known about the migratory habits of bull trout (*Salvelinus confluentus*) in the project area. There have been infrequent and isolated observations of bull trout in Elliott Bay, the Green/Duwamish River, and the portion of the Lake Washington watershed that are accessible to anadromous fish (Goetz et al. 2004). There is no clear pattern of their distribution or timing, but it is apparent that bull trout may occur in the project area.

Adult salmon migrating through Elliott Bay would be in the deeper portions of the project area. Chinook adults migrate along the Seattle shoreline from late June through mid-November, peaking between late September and late October (Grette and Salo 1986; Williams et al. 2001). Coho adults are present from early August to late January (Taylor Associates 1995; Warner and Fritz 1995).

Washington Department of Fish and Wildlife (WDFW) Priority Habitat and Species (PHS) Maps (2005) indicate that the closest forage fish spawning is much greater than 2 miles from the project area.

Federal and State Protected Species

The National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) have identified several species of ESA-listed salmon and steelhead (*O. mykiss*) present in and around the project area (NMFS and USFWS 2005; NMFS 2006). Chinook salmon from the Puget Sound Evolutionarily Significant Unit (ESU) of Chinook salmon are present; these fish are listed as threatened under the ESA. Coho salmon present include those from the Puget Sound/Strait of Georgia ESU, which is currently identified as an ESA species of concern. In addition, bull trout/Dolly Varden from the Coastal-Puget Sound Distinct Population Segment are present, and are listed as threatened under the ESA. NMFS (2006) proposed in March 2006 that steelhead be listed as threatened. NMFS is soliciting public input before the designation will be finalized.

Essential Fish Habitat

The Magnuson-Stevens Act requires Federal agencies to consult with NMFS on activities that may adversely affect Essential Fish Habitat (EFH). The Magnuson-Stevens Act defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity (NMFS 1999). Within the project area, NMFS has defined EFH for the Pacific Coast Groundfish and Coastal Pelagic Species assemblages present in coastal waters of Washington.

Pacific Coast Groundfish

The Magnuson-Stevens Act includes protection of EFH for 83 groundfish species, 56 of which were identified as potentially occurring in Elliott Bay (Parametrix 2004). Common groundfish that may occur in Elliott Bay include skates (e.g., longnose skate [*Raja rhina*]), rockfish (e.g. brown rockfish [*Sebastes auriculatus*] and copper rockfish [*S. caurinus*]), and flatfish (e.g., English sole [*Parophrys vetulus*] and starry flounder [*Platichthys stellatus*]). EFH for groundfish includes the entire project area up to mean higher high water. Where Pacific Coast Groundfish may occur in the project area, the sandy substrate in the shallow (-4 to -10 feet MLLW) and deep subtidal (deeper than -10 feet MLLW) areas provide habitat for flatfish and skates. Deep subtidal areas with structure such as pier piles, debris, and aquatic vegetation provide habitat typically associated with rockfish.

Coastal Pelagic Species

The Coastal Pelagic Species grouping includes four finfish (Pacific sardine (*Sardinops sagax*), Pacific (chub) mackerel (*Scomber japonicus*), northern anchovy (*Engraulis mordax*), and jack mackerel (*Trachurus symmetricus*)) and the invertebrate market squid (*Loligo opalescens*). NMFS classifies the five of these in the same species complex because of similar life histories and habitat requirements (NMFS 1999). Coastal Pelagic Species finfish are pelagic and are not generally associated with substrate. Although three of the four finfish species in this complex have been observed in Puget Sound, these species are not likely to rely on substrate or the water column in the project area for important living space and are not known to reproduce in this habitat. Market squid are likely to be found in the project area because they spawn in shallow subtidal areas and attach egg casings to hard objects within areas of sand or silt.

Marine Invertebrates

In a video diver survey, Taylor Associates (1995) identified a number of invertebrates of the typical Puget Sound assemblage as present in the benthic substrates of the project area. Common larger species include red crabs (*Cancer productus*), hairy crabs, (*Telmessus cheiragonus*), coon-stripe shrimp (*Pandalus danae*), sea stars (*Evasterias troschelii, Pisaster brevispinus*), anemones (*Metridium senile*), and Pacific octopus (*Octopus dolfeini*) (Parametrix 2004). Crabs, shrimp, and octopus would be expected to be found in and near protected areas with holes for refuge, while sea stars and anemones would be expected to be present on piles and on the benthic substrate.

Marine Mammals

Mammal species found in Elliott Bay that could potentially be found in the project area shoreline include harbor seal (*Phoca vitulina*) and California sea lion (*Zalophus californianus*). Their diet may occasionally include adult or juvenile salmon, although they typically feed on the groundfish, squid, and octopus of the benthic zone (Osborne et al. 1988).

Additional marine mammal species that may occur in Puget Sound, but are considered unlikely to enter Elliott Bay, include orca whale (*Orcinus orca*), humpback whale (*Megaptera novaeangliae*), Steller sea lion (*Eumetopias jubatus*), and leatherback sea turtle (*Dermochelys coriacea*). All four of these species are listed as threatened or endangered under the ESA. These species rarely enter Elliott Bay and are not expected in the project vicinity.

Birds

Birds that are expected to be commonly found along the Seattle project area shoreline include a variety of gulls, sparrows, and songbirds, among others. Typical bird species that may occur in the immediate vicinity of the project area and that utilize the nearby street trees and urban shoreline for perching, foraging, roosting, and nesting include: glaucous winged gull (*Larus glaucescens*), rock dove (*Columba livia*), American crow (*Corvus brachyrhynchos*), black-capped chickadee (*Parus atricapillus*), European starling (*Sturnus vulgaris*), red-breasted nuthatch (*Sitta canadensis*), house sparrow (*Passer domesticus*), and house finch (*Carpodacus mexicanus*).

A variety of waterfowl use the nearshore habitat of Elliott Bay and may occupy the project area regularly, occasionally, or seasonally (Parametrix 2004). Table 3 presents the waterfowl species that Parametrix (2004) identified as potentially occurring along the Central Seattle Waterfront.

*Table 3. Waterfowl Potentially Occurring in Project Area**

Common Name	Scientific Name
common loon	*Gavia immer*
yellow-billed loon	*Gavia adamsii*
Pacific loon	*Gavia pacifica*
red-throated loon	*Gavia stellata*
western grebe	*Aechmophorus occidentalis*
red-necked grebe	*Podiceps grisegena*
horned grebe	*Podiceps auritus*
eared grebe	*Podiceps nigricollis*
double-crested cormorant	*Phalacrocorax auritus*
Brandt's cormorant	*Phalacrocorax penicillatus*
pelagic cormorant	*Phalacrocorax pelagicus*
greater scaup	*Aythya marila*
lesser scaup	*Aythya affinis*
black scoter	*Melanitta nigra*
surf scoter	*Melanitta perspicillata*
white-winged scoter	*Melanitta fusca*
common goldeneye	*Bucephala clangula*
bufflehead	*Bucephala albeola*
American coot	*Fulica americana*
hooded merganser	*Lophodytes cucullatus*
red-breasted merganser	*Mergus serrator*
pigeon guillemot	*Cepphus columba*
belted kingfisher	*Ceryle alcyon*
great blue heron	*Ardea herodias*
herring gull	*Larus argentatus*
California gull	*Larus californicus*
western gull	*Larus occidentalis*
Bonaparte's gull	*Larus philadelphia*
ring-billed gull	*Larus delawarensis*
mew gull	*Larus canus*

* This table based on information provided in Parametrix (2004).

Raptors, including bald eagle (*Haliaeetus leucocephalus*), ospreys (*Pandion haliaetus*), and peregrine falcons (*Falco* *peregrinus*), have been observed along the Seattle waterfront. The WDFW PHS database (2005) documents no known bald eagle or osprey nests within 1 mile of the project area. The PHS database has documented that peregrine falcons, a federal species of concern under the ESA, have historically had nests atop two downtown buildings within 0.5 miles of the project area (WDFW 2005); however, neither nest location has been active since 2004 (Falcon Research Group http://www.frg.org).

Waterfowl use the air and water of the project area for habitat, and many of the other species may use the nearby street trees and urban shoreline for perching, foraging, roosting, and nesting.

Aquatic Vegetation

Aquatic vegetation (macroalgae) occurs in the project area in those locations with suitably large substrate to attach to and suitable light intensity (e.g., approximately less than -30 feet MLLW). Red, green, and brown macroalgae representing typical Puget Sound assemblages are present in the project vicinity, including those listed in Table 4. The suitable areas for macroalgae include the concrete rubble of the former Pier 61 (see Figure 6). A dense community of aquatic vegetation grows on the rubble, including extensive bull kelp in the offshore portions of the rubble (between approximately -15 to -30 feet MLLW). A rich assemblage of macroalgae grows on the rubble inshore of -15 feet and interspersed with the bull kelp at deeper depths.

Some macroalgae growth also occurs along the outer row of piles forming piers and on miscellaneous debris in the project area. The seawall and adjacent riprap support some macroalgae growth.

*Table 4. Aquatic Vegetation in Project Area**

Common Name	Scientific Name
Green Algae	
Sea hair	*Enteromorpha* spp.
Sea lettuce	*Ulva* spp.
Sea cellophane	*Monostroma grevillei*
Green tuft	*Cladophora columbiana*
Bryopsis	*Bryopsis corticulans*
Red Algae	
Criscross network	*Polyneura latissima*
Sea moss	*Endocladia muricata*
Red ribbon (dulse)	*Palmaria mollis (palmata)*
Bull-kelp laver	*Porphyra nereocystis*
Purple laver	*Porphyra perforata*
Veined fan	*Hymenena flabelligera*
Turkish towel	*Chondracantbus exasperatus*
Splendid iridescent seaweed	*Mazzaella splendens*
Winged rib	*Delesseria decipiens*
Violet sea fan	*Callophyllis violacea*
Turkish washcloth	*Mastocarpus papillatus*
Sea spaghetti	*Gracilaria sjoesttedtii* or *pacifica*
Rock crust	*Lithothamnion* spp.
Brown Algae	
Sugar kelp	*Laminaria saccharina*
Fringed sieve kelp	*Agarum fimbriatum*
Wireweed	*Sargassum muticum*
Seersucker	*Costaria costata*
Rockweed	*Fucus gardneri*
Sea cabbage	*Hedophyllum sessile*
Feather boa	*Egregia menziesii*
Desmarestia	*Desmarestia ligulata*
Soda straws	*Scytosiphon lomentaria*
Leathesia	*Leathesia difformis*
Ribbon kelp (wing kelp)	*Alaria marginata*
Bull kelp	*Nereocystis luetkeana*

* This table based on information provided in Taylor Associates (1995) and Parametrix (2004).

Riparian Vegetation

Riparian vegetation is sparse to absent in the project area; terrestrial vegetation is limited to existing street trees in planting structures lining Alaskan Way from the southern end of Piers 62/63 to the southern boundary of the project area.

OPERATIONAL EFFECTS AND MITIGATION

The potential effects of the proposed project on aquatic animals, vegetation, and birds were identified for each alternative. The potential beneficial and adverse effects of each alternative were evaluated using the project area information found in the information sources identified in the Affected Environment section of this technical appendix and current literature on marine nearshore ecology.

Effects Common to All Alternatives

Change in Overwater Structures

All alternatives will result in a change in overwater structures occurring in the project area. In the No Action/No Build Alternative, this change will occur through the eventual deterioration of Piers 62/63 and Waterfront Park. The timeframe for such deterioration is unknown, but it is assumed that as the piers become structurally unsound they will be demolished. All other alternatives would partially or fully demolish Pier 62/63 and Waterfront Park and replace them with a reconfigured pier design. The Aquarium expansion would reduce the amount of overwater structure from the 2.42 acres existing at the current Aquarium and Waterfront Park to 2.40 acres and would move the overwater structure further offshore from the seawall.

Aquatic Resources on Pier Structures

The piles supporting the piers provide habitat for a diverse community of sessile (stationary) and mobile animals. Along the outer margin of the piers with sufficient light, aquatic vegetation may also grow on piles. The removal of piles would include the removal of these communities, except for the mobile animals that are able to leave the area or drop off the piles during removal.

New piers constructed in all alternatives except the No Action/No Build Alternative would be built using fewer piles.

These piles would be steel or concrete. The reduced number of piles would reduce the amount of available habitat for pile communities. In addition, new steel or concrete piles may not be as suitable for supporting communities because their smooth surface can be difficult for animals to attach to.

Any potential effects of loss of pile habitat would be expected to be minimal since it is not a natural habitat type and numerous timber piles remain throughout the Seattle waterfront to support such communities. However, the design of any new piers could include methods to roughen the surface of new piles. This type of design consideration is supported by *Draft Seattle's Central Waterfront Concept Plan* (Seattle DPD 2006). Replacement habitat for the piling community could be provided by grouted tidal pools that are part of the foreshore beaches included in the Aqua Link, Connector, and Multi-Purpose Pier Alternatives.

Reduction in Light Availability for Aquatic Vegetation

For aquatic vegetation (e.g., macroalgae or kelp), large overwater structures such as the large piers in the project area block sunlight and do not allow sufficient light penetration through the water column to support vegetation growth. As a result, areas under large piers are often unvegetated. Areas that are shaded by the piers for long portions of the day can also be expected to have less aquatic vegetation than would normally occur.

Aquatic vegetation is a fundamental structural component of the nearshore ecosystem. Aquatic vegetation and the small organisms that grow on it are food for other animals and form the start of the food chain that supports all larger animals, including fish, crabs, and marine mammals. In this way, overwater structures can also reduce prey availability through the negative impacts on vegetation caused by the lack of light (Penttila and Doty 1990; Fresh et al. 1995; Olson et al. 1996; Haas et al. 2002). Aquatic vegetation also provides structure off the seafloor (substrate) that gives fish, crabs, and other animals a place to hide from potential predators.

In addition to the biological benefits of aquatic vegetation that are described above, aquatic vegetation can also reduce wave energy. This is especially true of kelp that grows all the way to the water surface. Any reductions in wave energy can benefit shoreline conditions by reducing water turbidity (murkiness), maintaining smaller sand and gravel substrates, and creating a lower energy environment for animals.

Each of the proposed alternatives, except the No Action/No Build Alternative, includes rebuilding piers and therefore would continue to limit aquatic vegetation growth under the structure. However, all four of those proposed alternatives would move the pier decks offshore in order to provide a corridor with little or no overwater structure along the seawall. By doing so, the four alternatives would provide additional habitat that is shallow enough to support aquatic vegetation. This type of design is highlighted in the *Draft Seattle's Central Waterfront Concept Plan* (Seattle DPD 2006) as a desirable element to improve habitat conditions.

Migration Disruption

Overwater structures can also affect aquatic animal movements along the shoreline. The effects of overwater structures on juvenile salmon movements have been a significant topic of interest because of the economic and cultural importance of salmon, as well as their protection under the ESA, as three species that may occur in the project area are listed as threatened[1]. Juvenile salmon, particularly fall Chinook and chum salmon, utilize the shallow nearshore areas of Puget Sound after their outmigration from the area's rivers. This is a vulnerable lifestage for juvenile salmon and their ability to feed, grow, and avoid predators during this time is believed to be a key factor affecting the population's survival (Beamish and Mahnken 1998; Furnell and Brett 1986; Holtby et al. 1990; Duffy 2003).

Juvenile salmon movements are varied when a large overwater structure is encountered (Nightengale and Simenstad 2001). Individuals of some species will readily pass under overwater structures, while others may delay before going around or going under. It has also been documented that schools of juvenile salmon may disband when overwater structures are encountered (Pentec 1997; Weitkamp and Schadt 1982; Weitkamp 1991). A recent study found that approximately half of tagged juvenile salmon swam under a large pier (ferry dock) and displayed no alterations to normal movement patterns (Thom et al. 2006). The

[1] Puget Sound Chinook, bull trout, and Hood Canal summer chum are listed as threatened under the ESA. Puget Sound steelhead are recommended by NMFS (2006) for listing as threatened, although this determination will not be finalized until the public review period is completed.

mechanisms for why overwater structures may alter juvenile salmon movements is generally attributed to the slow acclimation of their eyes to reduced light and the associated predation risks and inability to feed (Nightengale and Simenstad 2001)[2]. No studies are available that provide empirical data that any modification of juvenile salmon behavior associated with shoreline alterations results in changes in survival (NMFS and USFWS 2005).
As described above in the discussion of the reduced light availability under piers, every alternative except the No Action/No Build Alternative would move any new pier decks offshore in order to provide a corridor with little or no overwater structure along the seawall. This type of design element would improve upon the current setting in the project area by providing juvenile salmon with an open migration corridor in shallow water.

Potential for Increased Predation

Studies have suggested that migrating salmonids may not pass under an overwater structure, but instead be pushed further offshore where they may become more susceptible to predation from birds, mammals, and other fish. However, no conclusive evidence has been found to suggest that overwater structures contribute to increased predation on juvenile salmonids (NMFS and USFWS 2005).

The most intensive studies currently available about the effect of overwater structures on predation were conducted to investigate the potential effects of ferry terminals. It is presumed that these results are relevant to other types of overwater structures. Battelle (2002) investigated predation of juvenile salmon by birds and mammals at six Washington State Ferry terminals and paired reference sites in Puget Sound. In addition, an intensive survey of fish predators was conducted at one ferry terminal. The studies included SCUBA transects (benthic predatory fishes), snorkel transects (pelagic fishes), bird and marine mammal predatory surveys, salmon fry abundance surveys, documentation of nearshore fish assemblages during all diel phases using boat-deployed

[2] Nightengale and Simenstad (2001) summarized studies that estimated that at the juvenile stage, light-adapted chum and pink fry (considered representative of all salmon fry) required 30 to 40 minutes to fully adapt to dark conditions. The time for dark-adapted fry to adapt to light was 20 to 25 minutes. During these periods of transition, the juvenile salmon visual acuity ranges from periods of total blindness to a slightly diminished capacity. The starkness of the contrast between light and dark areas will affect acclimation times.

beach seines, collection of live potential fish predators and stomach content analysis, documentation of light measurements, and the use of Dual-frequency Identification Sonar (DIDSON) to document potential predators associated with the water column and terminals at night. The Battelle (2002) study concluded:

- Potential salmon predators were slightly more abundant at ferry terminals as compared with unmodified shorelines, although large aggregations were not observed on any occasion.
- The spatial distribution patterns of both bird and fish predators rarely overlapped with juvenile salmon oriented in surface waters close to shore.
- No evidence was found that avian, marine mammal, or fish predators consumed more juvenile salmon near ferry terminals than along shorelines without overwater structures.
- Analysis of fish diets provided one piece of conclusive evidence that juvenile salmon were not a major dietary component of predatory fish species during the study. (Only two juvenile salmon were observed in the diet of a single staghorn sculpin collected at the reference site; these salmon were undigested and likely consumed in the bag of the beach seine.)
- Interpretation of the abundance, distribution patterns, and diets of potential predators suggest that juvenile salmon did not experience biologically significant levels of predation near the ferry terminals studied.

Based on available literature, overwater structures are not expected to significantly increase predation risks to juvenile salmon.

Creation of Shallow Water Habitat

All alternatives except the No Action/No Build Alternative include the creation of shallow water habitat for the purpose of restoring a more natural and more diverse shoreline. The shallow water habitat would be created by placing several feet of material on top of the existing substrate. The general plan would be to use large volumes of clean material, such as sand that the U.S. Army Corps of Engineers dredges from the Duwamish River Turning Basin, to bring the seafloor elevation up to nearly design elevations. This sand base would be covered by several feet of larger materials to provide structural stability to the constructed habitat. The size of the larger material will be selected based on models predicting the sustainability of keeping materials in place given the wave energy of the project area. In the backshore, a sand substrate would likely be used. In the foreshore beach and habitat bench areas, these materials would likely be a mix of gravel, cobble, and quarry spall. Along the border of the created habitat and extending at a steep slope through the water would be larger material, such as large angular rock riprap, to contain the created habitat and keep it in place. The interstitial spaces of this large riprap would be filled with quarry spall. Riprap and quarry spall provide sufficiently large substrate to support larger species of aquatic vegetation, such as bull kelp, that require fairly large pieces of substrate to attach to in order to remain in place.

Addition of Large Substrate

The riprap and quarry spall material used to provide the structural stability to the created habitat will provide very different habitat than the sand and silt that is currently available, particularly along the relatively steep offshore slope where the created habitat reconnects to existing bathymetry. Riprap and quarry spall do not provide suitable habitat for burrowing animals such as clams and worms. These substrates also do not provide the interstitial spaces to support many types of macroinvertebrates that are typical components of fish diets.

Loss of Deep Subtidal Habitat

Common to all of the build alternatives would be the conversion of subtidal habitats that are used by various species of West Coast Groundfish, such as skates, rockfish, and flatfish. These EFH areas would be converted to shallower habitats with rockier substrates compared to the sand and silt substrates that currently are present. Displaced groundfish would continue to find nearby suitable habitat, which is common offshore from the created shallower habitat areas and throughout much of Elliott Bay. The amount of subtidal habitat converted to shallower habitat varies among the alternatives. Those with larger footprints would have proportionately larger groundfish EFH loss. The amount of subtidal habitat converted to intertidal habitats is presented under the section Effects of Individual Alternatives.

Potential for Increased Predation

The large rock riprap that could be included in the habitat enhancement design creates interstitial (between rock) crevices for potential predators to hide. Quarry spall would be placed on riprap offshore of the habitat bench to reduce the potential interstitial spaces. Juvenile salmon moving into or out of the habitat enhancement areas may also encounter increased predation risks as they transition between the enhanced and un-enhanced habitats. This transition would require juvenile salmon to move over a steeper riprap and quarry spall slope as they move from the created habitat at MLLW or higher to the unimproved areas at -10 to -30 feet MLLW.

Many salmon predators, including several that may occur in the project area, are associated with “reef-like” habitats such as may be provided by the riprap and quarry spall, although the quarry spall would reduce the availability of interstitial crevices for large predators to hide. A recently created habitat bench constructed approximately 0.5 mile north of the project area at the Olympic Sculpture Park may provide some fish presence data to inform whether the proposed habitats are being heavily utilized by potential predators to juvenile salmon.

The creation of shallow water habitat would improve the feeding setting for shorebirds, particularly piscivorous species. The beach and shallow water setting would provide new foraging areas for these birds.

Beneficial Effects

The proposed changes to overwater structures that are part of all alternatives would provide benefits to many aquatic animals and vegetation species, including juvenile salmon. The creation of shallow water habitat that is a component of all alternatives except the No Action/No Build Alternative would provide additional benefits for the aquatic animals and vegetation along the shoreline. Both of these project components are supported by the *Draft Seattle’s Central Waterfront Concept Plan* (Seattle DPD 2006) as being desirable habitat improvements for the shoreline. Following are descriptions of the habitat benefits provided by the proposed alternatives, although the benefits associated with the No Action/No Build Alternative would be more limited and on an uncertain timeframe.

Increased Habitat Diversity

The created habitat in the Aqua Link, Connector, and Multi-Purpose Pier Alternatives would provide habitat types that are not currently available along the Seattle downtown waterfront. The proposed habitat elements restore a range of habitats that represent a fully functioning ecosystem. The shallow water habitat would include areas of tidal pools to provide a diversity of habitat types along the shoreline that will, in turn, support a diverse range of animals and aquatic vegetation. The deep sand and silt habitat that would be converted to shallow water habitats is abundantly available along the Seattle waterfront, including in the offshore portions of the project area beyond the footprint of proposed habitat enhancement. Therefore, the proposed creation of shallow water habitats would not replace another habitat type that is otherwise limited in distribution throughout the Seattle downtown waterfront.

Increased Light Availability for Aquatic Vegetation

The removal of pier structures from along the seawall and the creation of shallow water habitat would expand the amount of habitat suitable for aquatic vegetation. A larger portion of the project area would be at water depths that receive sufficient sunlight to support plant growth. In addition, the design would almost exclusively include substrate sizes that are large enough to allow vegetation to grow. Currently, the sand and silt substrate throughout much of the project area does not support growth of large aquatic vegetation, such as macroalgae or eelgrass. The riprap and quarry spall that would occur along the offshore margin of the created habitat in order to maintain structural stability would provide significant increases in the amount of habitat providing sufficient light and substrate of adequate sizes to support growth of aquatic vegetation, particularly bull kelp. As described in earlier sections, aquatic vegetation contributes multiple beneficial features to the nearshore. The rich and dense aquatic vegetation community that could be expected from the added riprap is demonstrated by the extensive community that currently grows on the concrete slabs located at the former site of Pier 61 (see Figure 6). The concrete slabs support a dense, rich community of aquatic vegetation, including bull kelp, over all accessible surfaces that receive adequate light (Christiansen 2006). The proposed created habitat would effectively provide similar habitat along the entire length of the new habitat.

Open Migration Corridor

Opening up the shallow areas to create a corridor along the shoreline with little or no overwater structure would be a beneficial habitat improvement consistent with recommendations for promoting salmon recovery (e.g., W9SC 2005; Seattle DPD 2006). This design feature would provide a corridor through much of the project area for juvenile salmon to move through while foraging and migrating. The corridor would alleviate some of the previously identified concerns about potential survival risks associated with pier structures. A diverse community of other aquatic animals would also be expected to experience foraging and movement benefits resulting from the open corridor.

Shallow Sloping Migration Corridor for Juvenile Salmon

The creation of shallow sloping habitats, by all alternatives except the No Action/No Build Alternative, would improve migratory corridor conditions for juvenile salmon. This type of habitat enhancement would be consistent with the desirable habitat improvements identified in the *Draft Seattle's Central Waterfront Concept Plan* (Seattle DPD 2006).

Juvenile salmon, particularly fall Chinook and chum, depend upon shallow water habitats to avoid predators and grow rapidly (Fresh and Averill 2005; King County and Washington State Conservation Commission 2000; City of Seattle 2003). In general, when a range of water depths is available, juvenile salmon tend to occupy increasing water depths as their sizes increase (Fresh and Averill 2005). In this way, the smallest juvenile salmon will be primarily associated with the shallowest habitat. For smaller fish, very shallow water can offer a refuge from predation as larger piscivores cannot access those areas. During a rising tide, the shallow water along the waterline can also provide an abundance of upper intertidal and terrestrial prey items that are inundated by the rising water. In theory, this food source and the production of small prey items in the substrates throughout the intertidal zone would support increased growth rates among juvenile salmon. Based on the nearshore utilization of juvenile salmon, the naturally sloping low intertidal (-4 feet to +4 feet MLLW) and intertidal (-4 feet to +12 feet MLLW) habitats are considered most likely to be utilized by juvenile salmon. The supratidal habitats (higher than +12 feet MLLW) are beneficial to salmon by increasing the stability of the beach and providing areas to produce terrestrial prey items that would be accessible to juvenile salmon during especially high tides.

Every alternative except the No Action/No Build Alternative provides a gentle gradient 30-foot-wide habitat bench along the low intertidal zone near 0 feet MLLW. This habitat bench would provide a consistent corridor along the shoreline for juvenile salmon to migrate along. The corridor is at an elevation to be accessible to salmon during most tidal cycles while still being shallow for many tidal stages. The low intertidal elevation would also be highly productive for prey production. A mixed gravel and cobble substrate along the habitat bench would support aquatic vegetation, which in turn would support additional salmon prey production (Brennan et al. 2004).

Removal of Potential Chemical Contaminant Source

Many of the piles and decking forming the pier structures in the project area are creosote-treated wood, which can be a source of chemical contamination to sediments and water. Creosote is a wood preservative made from coal tar. The major chemicals associated with creosote that can impair the environment are PAHs, phenols, and cresols (Poston 2001). The potential impacts are associated with the accumulation of contaminants in the sediment and direct impacts to aquatic plants and animals that may colonize the pile, rather than in the water column. Intact creosote-treated materials release small amounts of creosote into the environment throughout their time in the aquatic environment (Poston 2001). As piles decay with age, the outer layers of wood may wear away or be broken away by contact, and accelerated creosote leaching from the interior can be expected (Hart Crowser 1997). The typical lifespan for a pile in the marine environment is highly variable depending on the technique and quality of introduction of the preservative to the wood. A general estimate for how long a pile will remain structurally intact with little decay is on the order of 30 to 40 years if there is no physically damaging contact during that time. During this 30 to 40 year timeframe, little creosote may be released; however, the onset of decay can rapidly increase the introduction of PAHs to the environment (Hart Crowser 1997).

The removal of existing piers composed of creosote-treated materials would remove a potential source of chemical contamination. This removal would be especially beneficial if conducted prior to the advanced deterioration of the piles.

New pier structures would be required to use steel or concrete piles, so no new source of potential contamination would be introduced to the environment.

Burial of Contaminated Materials

The proposed creation of shallow water habitat in all alternatives except the No Action/No Build Alternative would require placing material on top of existing substrates. As described in the Affected Environment section, the limited available information on the sediment chemistry of the existing substrates suggests that chemical concentrations exceed the Ecology SQS (Ecology 1995). For this reason, burying the materials with several feet of clean material will remove the contaminated sediment from the biologically active zone and can be considered to effectively address any chemical contamination issues in those portions of the project area.

The placement of clean materials on top of currently contaminated areas would be expected to support increased primary and secondary productivity and thereby improve prey resources for juvenile salmon and other aquatic animals. In addition, it will remove potential chemical contamination from entering the food web. If it is determined that sediments in the project area exceed SQS, then the project's approach to handling contaminated sediments (burial is proposed) would require the approval of Ecology, the Washington Department of Natural Resources, and other regulatory agencies.

Addition of Riparian Vegetation

With the exception of the No Action/No Build Alternative, all alternatives would provide a section of shoreline with riparian vegetation. Insects dropping from terrestrial vegetation would provide prey resources for juvenile salmon. In addition, fallen leaves from trees contribute organic material that starts the detritus-based food web upon which juvenile salmon feed. The importance of riparian vegetation to the diet of juvenile salmon in the nearshore has been suggested in several recent publications (e.g., Levings and Jamieson 2001; Brennan et al. 2004; Brennan and Culverwell 2004; Toft and Cordell 2006), although there is little information on the degree of contribution that may result from a small section of riparian trees in an urban setting. The riparian vegetation would also provide potential habitat for small birds.

Effects of Individual Alternatives

This section provides an overview of the effects that are specific to the features of each alternative. A key element of this effects assessment is the amount of shallow water habitat created and the change in overwater structures. A summary of the total amount of habitat under piers and not under piers by each alternative is provided in Table 5. With the exception of the No Action/No Build Alternative, each alternative includes two phases of action: one phase prior to the redesign of the Aquarium and a second phase incorporated into the Aquarium construction. The amount of habitat provided by each phase is described separately in the assessment of each alternative's effects.

*Table 5. Amount of Habitat (Acres) Provided by Each Alternative**

	Existing		No Action/No Build		Rebuild/ Preservation		Aqua Link		Connector		Multi-Purpose Pier	
Elevation Range (feet MLLW)	**Not Under Pier**	**Under Pier**	**Not Under Pier**	**Under Pier**	**Not Under Pier**	**Under Pier**	**Not Under Pier**	**Under Pier**	**Not Under Pier**	**Under Pier**	**Not Under Pier**	**Under Pier**
Greater than +12	0.00	0.00	0.00	0.00	0.30	0.02	0.43	0.04	0.39	0.03	0.39	0.03
+12 to +4	0.00	0.00	0.00	0.00	0.50	0.12	1.04	0.07	1.00	0.10	0.68	0.15
+4 to -4	0.02	0.21	0.17	0.06	0.88	0.27	1.23	0.43	1.21	0.54	1.01	0.39
-4 to -10	0.21	0.77	0.65	0.34	0.25	0.32	0.28	0.25	0.21	0.34	0.24	0.27
-10 to -30	1.02	2.64	2.46	1.19	1.23	1.69	1.00	1.09	0.78	1.41	0.99	1.42
Deeper than -30	4.22	1.28	5.15	0.33	2.95	1.84	2.42	2.10	2.25	2.09	2.50	2.30
Total	5.47	4.89	8.43	1.93	6.11	4.26	6.40	3.97	5.84	4.52	5.80	4.56

* See text and figures for an explanation of the elements of each alternative contributing to these changes.

No Action/No Build Alternative

The No Action/No Build Alternative would allow for the long-term deterioration of Piers 62/63 and Waterfront Park. This would result in the continued deterioration of the creosote-treated piles and decking that can be expected to allow the release of PAHs at an accelerated rate as pile deterioration increases. The removal of the piers would result in the removal of the creosote-treated piles and decking. This would remove these potential contaminant sources from the project area.

When the piers are eventually removed, there would be approximately 2.96 acres less overwater structure than currently exists. This reduction in overwater structures would allow for increased aquatic vegetation growth and food resource production in those areas. Due to the relatively deep existing water depths at Pier 62/63 and Waterfront Park, which limit light intensity on the seafloor, these beneficial effects would not be as extensive as in other alternatives that create shallow water habitat along areas next to the seawall with no overwater structure.

Rebuild/Preservation Alternative

The Rebuild/Preservation Alternative would rebuild Piers 62/63 in approximately the same configuration, except with a corridor of no overwater structure (other than access points) along the seawall (see Figure 2). The creation of a habitat bench to the north of the Aquarium and a backshore beach with habitat bench to the south would bury approximately 3.18 acres of existing subtidal habitat. As described above in the Creation of Shallow Water Habitat section of the Effects Common to All Alternatives, this burial would sacrifice the existing aquatic vegetation and animal communities. However, existing information suggests that these habitats are currently contaminated by one or more chemicals, so the placement of clean materials to create shallow water habitat could be expected to provide sediment cleanup benefits.

The riprap material providing the structural stability of the created habitat would potentially provide enhanced habitat for predators of juvenile salmon. This potential effect could be minimized by filling interstitial spaces with smaller material such as cobble or quarry spall in order to reduce the hiding places for potential predators.

The habitat bench created to the north of the Aquarium would be positioned inshore of the main deck of Pier 62/63 and would therefore provide a continuous shallow water corridor with little overwater structure. This is designed to provide substrate sizes such as gravel, cobble, and quarry spall that would support aquatic vegetation and a productive community of potential juvenile salmon prey items. A backshore beach with a habitat bench would be constructed in the area currently occupied by Waterfront Park. This beach would include riparian vegetation and public access. All design elements, including the backshore, wide intertidal beach, habitat bench, and riparian vegetation are expected to support a more productive community of potential juvenile salmon prey items than exists today.

This alternative would reduce overwater structure in the project area by approximately 0.63 acres compared to existing conditions. In the first phase of construction, approximately 0.45 acres of shallow subtidal habitat (between -4 feet and -10 feet MLLW) and deep subtidal habitat (deeper than -10 feet MLLW) with and without piers would be converted to intertidal habitat (-4 feet to +12 feet MLLW) that is not shaded by piers. In total, the creation of a habitat bench to the north of the Aquarium and a backshore beach with habitat bench to the south would convert approximately 1.85 acres of subtidal habitat to intertidal and supratidal habitats (higher than +12 feet MLLW), with 1.64 acres of it clear of overwater structure. This created habitat would add to the diversity of habitats available along the downtown Seattle waterfront and is intended to provide more favorable conditions for juvenile salmon growth and predator avoidance. The benefits to salmon species would be traded off against habitat loss for various groundfish, as noted in the section Effects Common to All Alternatives.

Aqua Link Alternative

The Aqua Link Alternative would remove Piers 62/63 and build a smaller pier that connects to the offshore margin of the Aquarium (see Figure 3). This would create a large open area in the northern end of the project area that would extend all the way to the Bell Harbor Marina (Pier 66) to the north.

The connections to the Aquarium by the new smaller pier and by a wide deck from Pier 57 would create a border of overwater structure around much of the project area. This border of overwater structure would potentially inhibit juvenile salmon movements from offshore to inshore and therefore reduce the number of juvenile salmon that may encounter any habitat enhancements made inside this area. Potential salmon movement into the habitat enhancement area south of the Aquarium would be more likely to be affected because the overwater structures surrounding this area are all more than 50 feet wide. For the habitat enhancement area north of the pier, the only overwater structures for fish entering from the north would be the proposed narrow access routes to the main pier. If these access routes are narrow (20 feet or less), then sufficient light may penetrate the water underneath the structure and therefore reduce the possibility that juvenile salmon may not migrate into the created habitats. The suggestion of access routes less than 20 feet wide is based upon studies of juvenile salmon movements around large structures in Puget Sound. These studies suggest that overwater structures that are not so wide as to create a stark light and dark contrast (i.e., less than approximately 20 feet wide) will not form a complete barrier to juvenile salmon (Roni and Weitkamp 1996; Thom et al. 2006).

The Aqua Link Alternative would include a pier-mounted wave attenuator on the connecting pier deck between Pier 57 and the Aquarium. This wave attenuator would reduce wave energy into the created habitats and provide a lower energy environment in the project area. Juvenile salmon have been found to congregate in low energy environments such as those that would be created. Weitkamp (2003) observed juvenile salmon schooling near the surface in the protected waters of the Bell Harbor Marina adjacent to the project area. Possible benefits for juvenile salmon provided by these conditions would be improved foraging success and decreased metabolic demands, both of which would support more rapid growth rates.

The habitat enhancements created by this alternative would bury approximately 5.21 acres of existing subtidal habitat, including EFH for various groundfish. This alternative would create a long section of backshore beach with a habitat bench. This created habitat would provide a wide intertidal and supratidal zone, including riparian vegetation. The riparian vegetation created along the backshore beach would provide a source of terrestrial organic material to contribute to the nearshore food web and potentially terrestrial-based prey resources for juvenile salmon. This backshore beach transitions into a foreshore beach with a habitat bench near the Aquarium. South of the Aquarium, another foreshore beach with a habitat bench would be constructed. These habitat enhancements would provide a wide intertidal zone along most of the project area that would be expected to support aquatic vegetation and a productive community of potential juvenile salmon prey items.

This alternative would reduce overwater structure in the project area by approximately 0.93 acres compared to existing conditions. In the first phase of construction, approximately 1.50 acres of subtidal habitat with and without piers would be converted to intertidal and supratidal habitat that is not shaded by piers. In the second phase of construction, approximately 1.47 acres of shallow subtidal and deep subtidal habitat with and without piers would be converted to intertidal and supratidal habitat with and without piers. In total, the habitat enhancements in this alternative would convert approximately 3.01 acres of habitat from subtidal habitat to intertidal and supratidal habitat, with 2.66 acres of it clear of overwater structure. This created habitat would add to the diversity of habitats available along the downtown Seattle waterfront and is intended to provide more favorable conditions for juvenile salmon growth and predator avoidance.

Connector Alternative

The Connector Alternative would rebuild Piers 62/63 in approximately the same location but with a wide corridor along the seawall with no overwater structure except for two access routes to the pier (see Figure 4). A pedestrian deck adjoining the Aquarium would also be located offshore of the seawall except for an access route. These two pier decks would be connected by a narrow footbridge. Overwater structures, including the narrow footbridge and the two access routes to the rebuilt Piers 62/63, form a border around most of the created habitat north of the Aquarium. These overwater structures would potentially inhibit juvenile salmon movements into the area between piers. However, as described above in the Aqua Link Alternative discussion, if the structures were designed to be relatively narrow (20 feet or less), then the possibility that juvenile salmon may not migrate into the created habitats would be reduced.

The habitat enhancements created by this alternative would bury approximately 5.24 acres of existing subtidal habitat, including EFH for various groundfish. This alternative would create a wide, shallow-water corridor along the project area except for under the Aquarium. The intertidal zone would be expected to support aquatic vegetation and a productive community of potential juvenile salmon prey items. The three foreshore beach areas would provide six sections of tidal pools to support a diverse community of aquatic vegetation and animals. The riparian vegetation created along the backshore beach would provide a source of terrestrial organic material to contribute to the nearshore food web and potentially terrestrial-based prey resources for juvenile salmon.

This alternative would provide a rock wave attenuator along the offshore margin of the foreshore beach and habitat bench constructed south of the Aquarium. This wave attenuator would be constructed of rock and extend from approximately -2 feet MLLW to +4 feet MLLW. The crest of the wave attenuator would be approximately 4 feet wide. This would create low energy habitat along the created habitat that would support juvenile salmon feeding and growth.

This alternative would reduce overwater structure in the project area by approximately 0.37 acres compared to existing conditions. In the first phase of construction, approximately 1.40 acres of subtidal habitat with and without piers would be converted to intertidal and supratidal habitat that is not shaded by piers. In total, the habitat enhancements in this alternative would convert approximately 3.05 acres of habitat from subtidal habitat to intertidal and supratidal habitat, with 2.56 acres of it clear of overwater structure. This created habitat would add to the diversity of habitats available along the downtown Seattle waterfront and is intended to provide more favorable conditions for juvenile salmon growth and predator avoidance.

Multi-Purpose Pier Alternative

The Multi-Purpose Pier Alternative would remove Piers 62/63 and build a similarly sized pier that is separated from the seawall except for three access routes, one of which is approximately 50 feet wide (see Figure 5). The new pier would connect to the Aquarium to create a border of overwater structure around a large portion of the habitat enhancements. This border of overwater structure would potentially inhibit juvenile salmon movements into the area between piers, particularly since access from any direction would require 50 feet or more under an overwater structure. Studies of juvenile salmon movements around structures in Puget Sound suggest that overwater structures more than 40 feet wide impede juvenile salmon migration (Roni and Weitkamp 1996).

The habitat enhancements created by this alternative would bury approximately 4.17 acres of existing subtidal habitat, including EFH for various groundfish. This alternative would provide a foreshore beach along the northern margin of the project area and a backshore beach along the southern margin. Along all areas except under the Aquarium, a habitat bench would provide a gently sloping shallow water corridor for juvenile salmon. The intertidal zone habitat created by this alternative would be expected to support aquatic vegetation and a productive community of potential juvenile salmon prey items. This alternative would include two sections of tidal pools to support a diverse community of aquatic vegetation and animals. The riparian vegetation created along the backshore beach to the south of the Aquarium would provide a source of terrestrial organic material to contribute to the nearshore food web and potentially terrestrial-based prey resources for juvenile salmon.

This alternative would reduce overwater structure in the project area by approximately 0.33 acres compared to existing conditions. In the first phase of construction, approximately 0.86 acres of subtidal habitat with and without piers would be converted to intertidal and supratidal habitat that is not shaded by piers. In total, the habitat enhancements in this alternative would convert approximately 2.41 acres of habitat from subtidal habitat to intertidal and supratidal habitat, with 2.04 acres of it clear of overwater structure. This created habitat would add to the diversity of habitats available along the downtown Seattle waterfront and is intended to provide more favorable conditions for juvenile salmon growth and predator avoidance.

Comparison of Alternatives

The deterioration and eventual removal of Piers 62/63 and Waterfront Park in the No Action/No Build Alternative would remove the largest amounts of overwater structure (nearly 3 acres). Among the remaining alternatives, the Aqua Link Alternative would provide the least overwater structure and approximately 1 acre less than is currently found in the project area.

The Connector and Aqua Link Alternatives would convert the largest amounts of habitat from subtidal to intertidal, which would be expected to increase production of potential prey resources for juvenile salmon. The No Action/No Build Alternative would not convert any habitat from subtidal to intertidal. Among the other alternatives, the Rebuild/Preservation Alternative would convert the least amount of habitat from subtidal to intertidal. Impacts on EFH for Pacific Coast Groundfish would be proportionate to the amount of subtidal habitat converted to intertidal habitats.

The Aqua Link Alternative would provide the most accessible habitat enhancement north of the Aquarium, as no structures occur offshore and the only overwater structures that juvenile salmon would need to go under would be two access routes that are less than 20 feet wide. The habitat enhancement to the south of the Aquarium that is proposed in the Aqua Link Alternative would be the least accessible area because of the wide areas of overwater structure bordering all sides of the enhancement area. Although overwater structures do not result in avoidance by all juvenile salmon, some avoidance would be expected. The Aqua Link Alternative would provide the most low energy habitat, whereas the No Action/No Build Alternative would provide the least.

The Aqua Link Alternative would provide the longest backshore beach section. The Connector Alternative would provide the most tidepools. The Aqua Link and Multi-Purpose Pier Alternatives would rebuild Piers 62/63 further south. This would create a large open area from the north end of the new pier to the Bell Harbor Marina (Pier 66).

CONSTRUCTION EFFECTS AND MITIGATION

Potential construction effects could occur during a multiple year construction schedule. The construction of every alternative except the No Action/No Build Alternative includes two phases of work. It is assumed that the first phase of work on Piers 62/63 would take 2 years to construct, with the first year focusing on demolition and removal of the existing structure. The second year would entail building the new pier. The second phase of work would take approximately 4 years to complete given the significant amount of work planned in redesigning the Aquarium.

Pier demolition may have land-based and barge-based components. Demolition materials may be moved from the project area by truck, rail, or barge. One or more of these methods may also deliver construction materials for the new structures.

Planned construction of the in-water components of the demolition and construction would occur during the approved work window for Elliott Bay between July 16 and February 15. Although NMFS and USFWS report that juvenile Chinook salmon and sub-adult and adult bull trout may be in the project area throughout the year, this work window for in-water work is standard for Elliott Bay and was recently used in the Piling Replacement project at the Aquarium (NMFS and USFWS 2005).

Effects Common to All Alternatives

Under all alternatives, construction activities could result in temporary effects to fish and aquatic resources from activity disturbance and sound pressure. Construction activities could result in temporary effects to aquatic resources from temporary water quality effects associated with localized turbidity from pile removal and installation. Based on the size of the construction footprint, specifically the new Piers 62/63;

the magnitude of temporary construction effects; and the associated level of disturbance, effects to fish from sound pressure (if only steel piles are used), and effects to aquatic resources from temporary increases in turbidity would be greatest for the Multi-Purpose Pier and Connector Alternatives. The Rebuild/Preservation and Aqua Link Alternatives would be expected to have slightly fewer effects because less overwater structure would be constructed. The No Action/No Build Alternative would have the fewest temporary construction effects.

Potential Turbidity Effects

Activities Creating Potential Turbidity

Pile Removal

All alternatives include the removal of piles as part of demolition activities at one or more of the piers. There are three methods to remove piles: vibratory hammer (for steel and timber), clamshell bucket (for timber), and cutting piles below the mudline (for concrete, steel, and timber).

The vibratory hammer works by vibrating the pile, thus loosening the sediment immediately around the pile. This allows the pile to be installed or lifted from the sediment. In addition to the numerous anecdotal accounts, recent monitoring by Washington State Ferries shows that the turbidity produced by removing piles with a vibratory hammer is expected to be temporary and minimal (Moffatt & Nichol and Anchor Environmental 2005).

For timber piles, a variation of removal with the vibratory hammer is the direct-pull method. Damaged piles that would break if vibrated can be removed by wrapping the pile with a cable and pulling it directly from the sediment with a crane. The direct-pull method would not be effective on significantly deteriorated piles because the method depends upon a solid pile core that will remain intact during the pulling effort.

A clamshell bucket is typically only used for pile removal when a pile is broken below the waterline and therefore difficult to locate and retrieve. The operator slowly sweeps the area near the piles with the clamshell bucket to locate the pile(s). When the bucket makes contact with a pile or set of piles, the operator opens up the bucket and grabs the timbers. This method produces a greater amount of turbidity than the vibratory hammer, but it is expected that the turbidity would be temporary and localized. Methods can be employed during pile removal with a clamshell bucket to reduce the potential turbidity. These methods include using the smallest size bucket required based on pile depth and substrate, lowering unsuccessful bucket attempts (i.e., only sediment, no piles) to the mudline before opening to redeposit the sediment to the seabed, and emptying the bucket of piles and debris on a lined barge.

Roni and Weitkamp (1996) monitored water quality parameters during a pier replacement project that used a clamshell bucket in Manchester, Washington. The study measured water quality before, during, and after pile removal, dredging, and pile replacement. The study found that turbidity at all depths nearest the construction activity was typically less than 1 nephelometric turbidity unit (NTU) higher than stations further from the construction area; this indicates that the turbidity generated by the pile replacement and dredging activities was very close to conditions where no such activities were occurring. Washington State turbidity standards require that the turbidity not exceed 5 NTU over background.

The third method that could potentially be used is to cut the pile below the mudline. This method is more time-consuming and labor intensive and is generally considered a least preferred method. This method may be used if a pile cannot be removed with the vibratory hammer or by using the direct-pull method, and if conditions do not allow the use of a clamshell bucket. The sediment around the pile would be excavated so the divers can access the pile 2 feet below the mudline. The pile would then be cut and removed, and the depression would be filled in with the excavated material. While this method produces a greater amount of turbidity than using a vibratory hammer, the effect is isolated and temporary. Cutting broken piles below the mudline may be necessary in areas where the fill material associated with any habitat enhancements would not bury the broken pile.

Pile Installation

Some turbidity would be expected during pile installation, as shown by anecdotal evidence and data obtained during pile installation with a vibratory hammer. The piles would be hollow; therefore, the pile would contain most of the turbidity that may be generated. The soil “plugs” that are created inside the pile as the pile is pushed into the sediment, however, would require special attention to ensure turbid waters do not enter Puget Sound. If there is sufficient room remaining in the pile to pour the concrete, then the soil plugs would be left in place. If the plug needs to be removed so concrete can be added, the soil plug would be removed by suction and placed in containers for proper disposal. Wet concrete would have to be contained within the pile to avoid toxic effects to aquatic resources from wet concrete or contaminated water.

Placement of Material to Create Habitat Enhancements

Placement of material to create habitat enhancement areas has the potential to increase turbidity. The amount and duration of water turbidity is related to the size of material that would be placed. Especially fine materials, such as silt and clay, tend to remain suspended in the water column longer than larger materials. Even sand settles out much faster than silt and clay material. Use of sand or larger substrate could reduce the potential for turbidity created by the suspension of the material being placed.

Placement of material could also cause turbidity by re-suspending sediment that forms the current seafloor surface. This material is primarily a mix of silt and sand and therefore could potentially increase turbidity for an extended period (hours). Minimizing the re-suspension of this material would also be important due to the potential for the material to be contaminated.

The potential for the re-suspension of existing seafloor sediments and material being placed could be reduced using several construction best management practices (BMPs). The potential for increased turbidity could be reduced by placing material using a clamshell bucket rather than dumping it from a barge. This potential could be further reduced by lowering the bucket to the sediment-water interface before opening. Use of a silt curtain would also reduce potential turbidity. Additional BMPs are described in a later section of this technical appendix.

Potential Effects to Aquatic Resources from Turbidity

A greater quantity of data is available on effects to aquatic resources from turbidity generated during dredging and disposal activities and on changes in sediment loads originating from within watersheds than there is for pile removal and installation activities. Turbidity from dredging and sediment loading is expected to exceed temporary turbidity levels generated from pile removal and installation because dredging involves the removal and disturbance of significantly greater amounts of sediment, and sediment loading (as a function of geomorphic erosional processes, watershed development, etc.) is expected to contribute more sediment to marine waters.

The effects to aquatic resources from suspended sediments would be a function of the amount of time sediments are suspended (Newcomb and MacDonald 1991) and the frequency of sediment exposure (Shaw and Richardson 2001).

Invertebrates and Crustaceans

Elevated levels of suspended sediments can have wide-ranging effects on pelagic and benthic invertebrates (Wilbur and Clarke 2001). Effects can be classified as direct effects to an organism due to abrasion; clogging of filtration mechanisms, which can interfere with ingestion and respiration; and in some cases, smothering and burial, which result in mortality (Berry et al. 2003). Indirect effects could occur from changes in light attenuation leading to changes in feeding efficiency and behavior, and alteration of habitat (substrate composition) (Donahue and Irvine 2003). Effects such as reduced growth and mortality of invertebrates could occur if sediments are suspended over several days and if concentrations are high (e.g., greater than 1,000 mg/l).

For this project, sediments temporarily suspended from pile removal and installation are expected to be flushed by daily currents and tidal exchanges, and concentrations are expected to be much lower than concentrations reported during dredging operations (e.g., 700 mg/l at the surface and 1,100 mg/l at the bottom). The effects to invertebrates and crustaceans are expected to be minimal.

Aquatic Plants

Changes in underwater light due to increases in suspended sediment concentrations can affect aquatic plants (Best et al. 2001). Long durations of exposure and high concentrations of suspended sediment can limit plant growth and affect plant distribution. Aquatic plants are also subject to burial; however, different species have different tolerances for sediment accretion (Fonseca and Fisher 1986). Effects to aquatic plants from temporary turbidity are expected to be minimal because currents and tides are expected to flush suspended sediments and concentrations are expected to be low.

Fish

Of all the taxonomic groups, fish, particularly salmon, have received the most attention from researchers studying the effects of suspended sediments on aquatic resources. The potential effects of increased turbidity on salmonids have been investigated in a number of dredging studies (Servizi and Martens 1987 and 1992; Emmett et al. 1988; Noggle 1978; Simenstad 1988; Redding et al. 1987; Mortensen et al. 1976; and Berg and Northcote 1985). The findings of these studies are applied here to other fish species. There are several mechanisms by which suspended sediment can affect juvenile salmonids, including direct mortality, gill tissue damage, physiological stress, and behavioral changes. Since adult fish can avoid the area, the discussion of impacts to fish is directed at juveniles that have a greater chance of being unable to avoid the effects of construction activities.

Direct mortality from extremely high levels of suspended sediment (at all life stages) has been demonstrated at concentrations far exceeding those caused by typical dredging operations. Based on an evaluation of seven clamshell dredge operations at sites with fine silt or clay substrates, LaSalle (1988) determined that suspended sediment levels of 700 mg/l and 1,100 mg/l at the surface and bottom, respectively, would represent the upper limit concentration expected adjacent to the dredge source (within approximately 300 feet). Much lower concentrations (50 to 150 mg/l at 150 feet from the dredge source) are expected at sites with coarser sediment. Because direct mortality occurs at turbidity levels that far exceed typical dredging operations, and because levels of suspended sediment from dredging far exceed levels generated by pile removal and installation, direct mortality from suspended sediment is not expected to occur during pile removal or installation activities.

Studies have also indicated that suspended sediment concentrations occurring near dredging activity would not cause gill damage in salmonids. Again, data on dredging, which is more readily available, are used to evaluate effects from much higher levels of turbidity than that generated by pile removal or installation. If dredging does not significantly affect fish, it is assumed that pile removal and installation would also not affect fish. Servizi and Martens (1992) and Redding et al.

(1987) found that the appearance of gill tissue was similar for control fish and those exposed to high, medium, and low concentrations of suspended topsoil, ash, and clay. Based on the results of these studies, juvenile and sub-adult salmonids, if any are present, are not expected to experience gill tissue damage caused by pile removal or installation activities. Furthermore, given the ability of adult salmonids to avoid areas with less than favorable conditions, adult salmonids are not expected to experience gill tissue damage as a result of the proposed project.

Suspended sediments have been shown to cause stress in salmonids, but at concentrations higher than those typically caused by dredging (Redding et al. 1987). Therefore, by applying these dredging results to pile installation and removal, it is concluded that the concentrations of suspended sediment caused by pile removal and installation would not have physiological effects on salmonids or other fish species in the project area.

Behavioral responses to elevated levels of suspended sediment include changes in feeding and migratory behavior (Servizi 1988; Martin et al. 1977; Bisson and Bilby 1982; Berg and Northcote 1985). Since suspended sediment levels from pile removal and installation are not expected to reach those of dredging, migratory or feeding disruptions are not likely to occur from pile removal or installation activities.

Potential Noise (Sound Pressure) Effects

Pile Removal

The noise produced during pile removal activities could cause aquatic animals and birds to avoid the project vicinity. None of the removal methods produces a noise loud enough to cause a pressure wave that would harm these resources.

Pile Installation

All alternatives except the No Action/No Build Alternative would include the installation of piles as part of construction of new piers. These piles would be made of hollow steel or hollow concrete. There are two methods commonly used to install piles: vibratory hammer and impact hammer. Vibratory hammers are generally considered the more preferable method in the aquatic environment; however, driving a pile through particularly dense material sometimes requires using impact hammers. Vibratory hammers drive piles into the substrate by vibration.

Impact hammers install piles by repeatedly striking the top of the pile with a heavy rod. Impact pile driving can take 15 to 45 minutes per pile, depending on soil conditions. When impact hammers strike the top of the steel pile, a pressure wave travels down the pile and causes the pile to resonate radially and longitudinally (like a bell). The sound pressure generated during pile driving steel piles over 24 inches in diameter has the potential to injure or kill fish in the immediate vicinity of project activities. Fish kills have been documented along the West Coast using impact hammers, although a fish kill does not always occur. It is uncertain why some pile-driving projects result in fish kills and other, similar pile-driving projects do not. Sound attenuation systems, such as bubble curtains, can be installed around the pile to be installed and effectively minimize the potentially harmful pressure waves produced upon impact.

Installation of Hollow Steel Piles

Steel piles may be installed using a vibratory hammer. The use of the vibratory hammer is preferred because there is no “bell-like” noise produced. However, the steel piles often need to be “proofed” to seat them in the sediment. Proofing requires the use of an impact hammer to complete installation.

The data on the effects of pile driving on fish are limited, and the results are equivocal. Several studies have been undertaken, but there is no conclusion as to the effects relative to distance, species, exposure time, the success of noise attenuation devices, or fish behavior. There are no studies that have examined longer-term effects of exposure to pile-driving sounds that may lead to delayed death, or other behavior changes that could lead to a delayed death. Nor have studies examined the non-mortality responses of fish (e.g., tissue breakdown or hearing loss) at a distance from the source (Hastings and Popper 2005).

Field studies conducted during pile-driving activities in Everett have shown varying degrees of disturbance to juvenile salmonids (Bonar 1995; Feist et al. 1992; Anderson 1990). In all of these studies, salmonid distribution within an area where pile driving was occurring was highly variable due to changing environmental conditions. Bonar (1995) and Feist et al. (1992) found that pile driving had no effect on juvenile salmonid abundance. Anderson (1990) found subtle differences in fish abundance and schooling, suggesting that fish avoided the construction activity to some degree. Pile driving did not displace fish from the construction site or offshore into deeper water (Anderson 1990; Feist et al. 1992). Fish were often found milling around the pile-driving rig while it was operating, with no apparent effect on their behavior (Bonar 1995). Fish located 50 feet from the activity did not show a startle response when pile driving was initiated.

Adult salmonids can be in the immediate vicinity of pile driving without suffering apparent harm or behavioral changes, such as delayed migration (Grette 1985). Washington State Ferries inspectors on site during pile-driving activities have observed that adult salmon have been known to “stop and watch” pile-driving activities, and leave the area after pile driving is complete. Research conducted by the Port of Vancouver, British Columbia, suggests that fish over approximately 6 inches (15.4 centimeters) do not appear to suffer the same types of injury from pile driving that juveniles do (Desjardin 2003).

In summary, potential effects to fish from installing hollow steel piles with an impact hammer include mortality, injury, stress, tissue damage, and behavioral changes. The specific effects, however, depend on the duration of impact hammer activities and the use of best management practices to attenuate the noise.

Installation of Hollow Concrete Piles

Hollow concrete piles cannot be installed with a vibratory hammer; rather, they must be installed with an impact hammer. The elasticity of steel piles is greater than that of concrete piling and, therefore, the propagation of underwater pressure waves is expected to be less for concrete piles. Hastings and Popper (2005) prepared a comprehensive compendium of research on the effects of sound on fish. One of the recent pile-driving studies identified in this report was the *Port of Oakland Preliminary Study* (Hastings and Popper 2005), in which 24-inch concrete piles were driven using a diesel impact hammer. Caged fish were exposed to four minutes of pile driving. The results showed no differences in mortality between sound-exposed and control animals (Hastings and Popper 2005). However, this study does not provide information on the effects of pile driving for longer periods of time.

Potential effects on adult salmon are expected to be limited because fish in this life history stage are highly mobile, can avoid the immediate project area, and have been shown to be less sensitive than juvenile salmon to both modifications in their migration routes and direct effects from sound pressure. Pile driving and other construction will not occur during outmigration periods for juveniles, reducing the potential for noise effects to juvenile Chinook salmon.

Installation of concrete piles is not expected to result in any permanent adverse effects on aquatic resources.

Burial of Existing Aquatic Resources

The placement of material to create the shallow water habitat will bury all existing communities within the footprint of the material placement. Although there are some differences between alternatives, in general, the areas that would be buried in the build alternatives are currently between -5 feet and -40 feet MLLW and are predominantly a mix of sand and silt. These areas currently support a community of benthic and epibenthic organisms such as clams, crabs, sea stars, worms, and numerous smaller animals (macroinvertebrates) that are important food resources for juvenile salmon and other fish. These subtidal habitats are used by various groundfish species, such as skates, rockfish, and flatfish, which would be displaced.

In other portions of the areas that would be buried, larger substrate such as riprap, concrete slabs, derelict piles, or other miscellaneous debris provides material for aquatic vegetation and sessile animals to grow on. In this portion of Elliott Bay, rich communities of aquatic vegetation, including red, brown, and green macroalgae, will grow on all suitable substrates (Christiansen 2006). Recolonization of these areas by plants and aquatic vegetation from adjacent areas and/or settling out from the water column is expected to be rapid (see e.g., Thom et al. 1986; Simenstad and Thom 1996).

Release of Chemical Contaminants

The removal of the creosote-treated piles would be expected to result in the release of PAHs into the environment. NMFS and USFWS (2005) identified two potential ways for increased long-term contamination that could result from the removal creosote-treated piles. One way is through the re-exposure of the buried portion of piles during their removal. The creosote on the surface of piles that have been buried in the anoxic zone would be expected to be highly volatile as it is re-exposed to the water column. The second way is through the potential release of droplets of fresh creosote from the piles as piles are being pulled. Because these droplets are heavier than water, they would sink to the bottom and very likely be undetectable in the water column.

The removal of piles would also produce localized and temporary disturbances of potentially contaminated sediments. The vibratory hammer pile pulling technique would loosen sediment around the piles and would therefore be expected to lift some amount of sediment into the water column during pile extraction. The direct pull method would disturb sediments immediately adjacent to the piles. The clamshell technique would excavate a larger area around each pile and cause relatively more turbidity increases than the other methods and may require offsite disposal of sediments.

Potential Introduction of Additional Overwater Structures

The demolition and construction activities may include the use of barges for staging, stockpiling, and placing of materials. One or more barges may be tied up to Piers 62/63 during extended portions of the construction period. Typical barge dimensions may be 150 to 200 feet long by 70 feet wide by 12.5 feet deep and therefore each barge would provide 0.24 to 0.32 acres of additional overwater structure.

The additional overwater structure would expand the footprint of dark areas for juvenile salmon to navigate around or under. The barge effects would be expected to differ from pier effects because the barges extend into the water column and would not allow juvenile salmon to migrate near the surface as they typically do. As a result, juvenile salmon would be more likely to travel around the dark areas (rather than through) by moving to the deeper offshore areas where they may become more susceptible to predation from birds, mammals, and other fish.

An extended presence of barges may affect aquatic vegetation under and adjacent to the barges by reducing light penetration. This would reduce the amount of habitat available for fish and invertebrates in the project area.

Construction Best Management Practices

Construction measures implemented to minimize potential construction effects on fish and aquatic resources would be incorporated into the construction methodology. These measures may be refined or revised upon finalization of the preferred alternative and as construction plans are developed. Additional measures may be taken as required by agency approval.

- Short-term construction effects on salmonids would be significantly reduced through timing restrictions imposed by resource agencies, which are enforced from March 15 to July 15 for the protection of Puget Sound Chinook salmon, and from February 15 through July 15 for the protection of bull trout. NMFS and USFWS have established allowable work windows when listed juvenile salmonids are absent or likely would not occur in areas of Puget Sound. No forage fish work windows would be applied because forage fish are not found at or near the project area.
- Silt curtains could be installed and maintained around the work area during pier demolition.
- Pile installation noise will be minimized by using a vibratory hammer rather than an impact hammer, when possible. Substrate conditions may require using an impact hammer. Pile proofing would be conducted as necessary with an impact hammer.
- Noise-attenuating measures, such as installation of a bubble curtain, would be taken to reduce noise effects to fish and other aquatic species during installation of steel piles with an impact hammer.
- All fill and riprap materials will be placed by moving the dredge bucket to the surface of the existing substrate before opening in order to minimize entrainment of existing substrates and to minimize turbidity.
- The contractor would be required to follow an approved Spill Prevention, Containment, and Control (SPCC) Plan, including maintaining spill response materials on site.
- The contractor would be required to follow an approved concrete containment plan to ensure no wet cement will fall or spill into the water.

- The contractor would be required to follow an approved plan to ensure a clean construction site is maintained and to reduce the potential for debris entering surface waters.
- Turbidity would be monitored to ensure water quality standards are met.
- Construction equipment and vehicles would be maintained to prevent them from leaking fuel or lubricants.
- For equipment used in and over water, lubricants that are not petroleum-based would be used to the extent feasible.
- Any floating debris generated during construction would be retrieved using a skiff and net, and collected debris will be disposed of onshore in an appropriate manner.
- Excavated sediments, if any, or sediments clinging to removed piles would be contained on a barge or pier deck. The barge storage area would consist of a row of hay or straw bales and/or filter fabric placed around the perimeter of the barge.
- A floating containment boom surrounding in-water work areas associated with timber piles would be used.
- Any debris in the containment boom by the end of the workday or when the boom is removed, whichever occurs first, would be removed and captured material would be disposed of in an upland disposal site.
- Whenever activities would generate sawdust, drill tailings, or wood chips from treated timbers, tarps or other containment material would be used to prevent debris from entering the water. If tarps could not be used (because of the location or type of structure), a containment boom would be placed around the work area to capture debris and cuttings.

Effects of Individual Alternatives

No Action/No Build Alternative

The No Action/No Build Alternative would delay all construction activities until Piers 62/63 and/or Waterfront Park are structurally unsound and require removal for safety purposes. The demolition of the decayed piers could be a more significant effort than a demolition effort conducted while much of the pier materials are structurally intact. The demolition of the decayed piers could also release more PAHs to the environment than has been described above in the section on Pile Removal. Removal of the decayed, creosote-treated wood in the pier decks and piles may result in the splintering of the wood and subsequent release of numerous wood fragments and chemical contaminants (e.g., PAHs) to the environment. The onset of decay in creosote-treated piles can rapidly increase the introduction of PAHs to the environment (Hart Crowser 1997).

BMPs during construction could help minimize these potential effects. Placement and maintenance of a silt curtain around the work area would reduce the transport of wood fragments. The effectiveness of a silt curtain would be enhanced by having floating wood fragments removed from the work area, especially along the silt curtain, on a regular basis.

Rebuild/Preservation Alternative

The Rebuild/Preservation Alternative would have no unique potential construction effects. All potential effects described above in the Effects Common to All Alternatives section would apply to this alternative.

Aqua Link Alternative

The Aqua Link Alternative would have no unique potential construction effects. All potential effects described above in the Effects Common to All Alternatives section would apply to this alternative.

Connector Alternative

The Connector Alternative would have no unique potential construction effects. All potential effects described above in the Effects Common to All Alternatives section would apply to this alternative.

Multi-Purpose Pier Alternative

The Multi-Purpose Pier Alternative would have no unique potential construction effects. All potential effects described above in the Effects Common to All Alternatives section would apply to this alternative.

Comparison of Alternatives

The No Action/No Build Alternative would have the fewest construction-related impacts of all alternatives, since no overwater structure would be rebuilt. The No Action/No Build Alternative would provide the greatest potential for release of chemical contaminants into the environment if pier removal is not conducted until the structural integrity of the piles is significantly depleted.

The Multi-Purpose Pier and Connector Alternatives would include the largest new pier structures and would therefore have the greatest potential for impacts related to pile driving. The Aqua Link and Connector Alternatives would create the largest habitat enhancement areas and would therefore have the greatest potential for effects related to sediment re-suspension.

CUMULATIVE EFFECTS

The project area is centrally located along the downtown Seattle waterfront. Several significant independent shoreline activities are in the developmental stage along the Seattle waterfront. The largest of these potential projects is the replacement of the seawall. This would extend along more than 7,200 feet of the shoreline. An EIS has been prepared by the Washington State Department of Transportation, City of Seattle, and the Federal Highway Administration to examine a range of alternatives.

Another significant shoreline project that is in the early stages of development is the reconfiguration of the Washington State Ferries Colman Dock Ferry Terminal at Pier 52. One concept for this work is to move the car holding area deck offshore in order to provide a corridor of light along the seawall with no overwater structure.

A cumulative beneficial effect of these projects is for the creation of a shoreline corridor that is much more favorable to juvenile salmon and other aquatic animals and vegetation. The habitat enhancement features of these projects would add to the improvements that would be provided by the proposed alternatives. A key concern for juvenile salmon migrating along the downtown Seattle waterfront is the lack of low energy, high productivity habitat that would enable the fish to grow rapidly, thereby outgrowing potential predators. The cumulative effect of these projects would be a series of enhanced habitat areas along the Seattle waterfront that would potentially enhance juvenile salmon growth rates.

Another cumulative beneficial effect on the aquatic environment from this proposal and other waterfront work would be the cumulative removal of creosote-treated piles and decking materials from the aquatic environment of Elliott Bay. This effect would be a long-term benefit.

REFERENCES

Anderson, J.J. 1990. Assessment of the Risk of Pile Driving to Juvenile Fish. Fisheries Research Institute. University of Washington, Seattle, Washington.

Battelle Marine Sciences Laboratory (Battelle). 2002. *Evaluation of Methods to Increase Light Under Ferry Terminals.* Prepared for the Washington State Department of Transportation. April 2002.

Beamish, R. J., and C. Mahnken. 1998. Natural regulation of the abundance of coho and other species of Pacific salmon according to a critical size and critical period hypothesis. NPAFC Doc. No. 319. 26p.

Berg, L. and T.G. Northcote. 1985. *Changes in Territorial, Gill Flaring and Feeding Behavior in Juvenile Coho Salmon (Oncorhynchus kisutch) following Short-term Pulses of Suspended Sediment*. Can. J. Fish. Aquat. Sci. 42:1410-1417.

Berry, W., N. Rubinstein, B. Melzian, and B. Hill. 2003. The Biological Effects of Suspended and Bedded Sediment (SABs) in Aquatic Systems. USEPA Internal Report 58 9.

Best, E.P.H., C.P. Buzzellie, S.M. Bartell, R.L. Wetzel, W.A. Boyd, R.D. Doyle and K.R. Campbell. 2001. *Modeling Submerged Macrophyte Growth in Relation to Underwater Light Climate: Modeling Approaches and Application Potential.* Hydrobiologia. 444:43-70.

Bisson, P.A. and R.E. Bilby. 1982. *Avoidance of Suspended Sediment by Juvenile Coho Salmon*. N. Amer. J. Fish. Manage. 2:371-374.

Bonar, Dr. D.B. 1995. *Juvenile Salmonid Outmigration at the Everett Homeport: Effects of Shoreline Shading and Offshore Pile Driving Activities.* Aquatic Environmental Services.

Brennan, J. S., K. F. Higgins, J. R. Cordell, and V. A. Stamatiou. 2004. *Juvenile Salmon Composition,* *Timing, Distribution, and Diet in Marine Nearshore Waters of Central Puget Sound, 2001-2002*. Prepared for the King County Department of Natural Resources and Parks, Seattle, WA.

Brennan, J.S., and H. Culverwell. 2004. Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems. Published by Washington Sea Grant Program. Seattle, WA.

Christiansen, J. 2006. Personal communication regarding existing habitat conditions in Seattle Central Waterfront project area. February 2006.

City of Seattle. 2003. Seattle's Urban Blueprint for Habitat Protection and Restoration. Prepared by City of Seattle's Salmon Team. December 2003.

Desjardin, D. 2003. Personal communication during Pile Driving Conference Calls between the Ports of Vancouver, Seattle and Tacoma, Washington State Ferries, Washington State Department of Transportation, U.S. Fish and Wildlife, Washington Department of Fish and Wildlife, and NOAA Fisheries. January 15, 2003 and February 20, 2003.

Donahue, I. and K. Irvine. 2003. *Effects of Sediment Particle Size Composition on Survivorship of Benthic Invertebrates from Lanke Tanganyika, Africa.* Archive fuer Hydrobiolgie. 157:131-144.

Duffy, E.J. 2003. Early marine distribution and trophic interactions of juvenile salmon in Puget Sound. Master's thesis, University Of Washington. Seattle, Washington. 169 pp.

Washington State Department of Ecology (Ecology). 1995. *Elliott Bay Waterfront Recontamination Study*. Volume I: Field Investigation Report (#95-335) and Volume II Data Evaluation and Remedial Design Recommendations Report (#95-607). Prepared for Washington Department of Ecology.

Ecology. 2004. SEDQUAL Sediment Quality Information System. Washington State Department of Ecology.

Emmett, R.L., G.T. McCabe Jr., and W.D. Muir. 1988. *Effects of the 1980 Mount St. Helens Eruption on Columbia River Estuarine Fishes: Implications for Dredging in Northwest Estuaries*. Pages 75-91 in C.A. Simenstad, ed. Effects of Dredging on Anadromous Pacific Coast Fishes. University of Washington, Seattle, Washington.

Falcon Research Group. http://www.frg.org.

Feist B.E., J.J. Anderson, and R. Miyamoto. 1992. *Potential Impacts of Pile Driving on Juvenile Pink (Oncorhynchus gorbuscha) and Chum (O. keta) Salmon Behavior and Distribution*. University of Washington School of Fisheries. May 1992.

Fonseca, M.S. and J.S. Fisher. 1986. “A Comparison of Canopy Friction and Sediment Movement between Four Species of Seagrass with Reference to their Ecology and Restoration.” Marine Ecology Progress Series. 29:15-22.

Fresh, K.L., B. Williams, and D. Penttila. 1995. Overwater structures and impacts on eelgrass (Zostera marina) in Puget Sound, Washington. Pages 537-577 in Puget Sound Research ’95 Proceedings. Puget Sound Water Quality Authority, Olympia, Washington.

Fresh, K. and D. Averill. 2005. Salmon in the Nearshore and Marine Waters of Puget Sound. In: Redmond et al. [eds.] Regional Nearshore and Marine Aspects of Salmon Recovery in Puget Sound. Delivered to Shared Strategy for Puget Sound for inclusion in their regional salmon recovery plan.

Furnell, D.J., and J.R. Brett. 1986. Model of monthly marine growth and natural mortality for Babine Lake sockeye salmon (*Oncorhynchus nerka*). Can. J. Fish. Aquat. Sci. 43: 999-1004.

Goetz, F.A., E. Jeanes, E. Beamer, and six authors. 2004. Bull Trout in the Nearshore – Preliminary Draft. Prepared by the U.S. Army Corps of Engineers, R2 Resource Consultants, Skagit River System Cooperative, Seattle City Light, and King County Department of Natural Resources.

Grette, G.B. 1985. *Fish Monitoring during Pile Driving at Hiram H. Chittenden Locks, August-September 1985.* Prepared for the U.S. Army Corps of Engineers, Seattle District. Prepared by Evans-Hamilton, Inc., Seattle, WA.

Grette, G.B. and E.O. Salo. 1986. The status of anadromous fishes of the Green/Duwamish River system. Prepared for the U.S. Army Corps of Engineers, Seattle District. Prepared by Evans-Hamilton, Inc., Seattle, WA.

Haas, M.E., C.A. Simenstad, J.R. Cordell, D.A. Beauchamp, and B.S. Miller. 2002. *Effects of Large Overwater Structures on Epibenthic Juvenile Salmon Prey Assemblages in Puget Sound, Washington*. Technical Report T1803-30, School of Aquatic and Fishery Sciences, University of Washington. Prepared for Washington State department of Transportation (WSDOT).

Hart Crowser. 1997. Pier 64/65 Sediment Quality Assessment. Prepared for the Port of Seattle.

Hastings and Popper. 2005. Effects of Sounds on Fish. January 28, 2005.

Holtby, L.B., B.C. Anderson, and R.K. Kadowaki. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 47(11): 2181-2194.

King County and Washington State Conservation Commission. 2000. Habitat Limiting Factors and Reconnaissance Assessment Green/Duwamish and Central Puget Sound Watersheds Water Resource Inventory Area 9 and Vashon Island.

LaSalle, M.W. 1988. *Physical and Chemical Alterations Associated with Dredging: An Overview*. Pages 1-12 in C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington, Seattle, Washington.

Levings, C. and G. Jamieson. 2001. Marine and estuarine riparian habitats and their role in coastal ecosystems, Pacific region. Canadian Science Advisory Secretariat, Research Document 2001/109. 41pp.

Makers. 2005. Seattle Central Waterfront Park Planning Feasibility Study. Prepared for Seattle Parks and Recreation. December 2005.

Martin, J.D., E.O. Salo, and B.O. Snyder. 1977. *Field Bioassay Studies on the Tolerance of Juvenile Salmonids to Various Levels of Suspended Solids*. University of Washington School of Fisheries Research Institute. Seattle, WA. FRI-UW-7713.

Moffatt & Nichol and Anchor Environmental. 2005. Draft Aquatic Plants and Animal Resources Discipline Report Mukilteo Multimodal Ferry Terminal. Prepared for Federal Transit Administration, Washington State Department of Transportation, and Washington State Ferries.

Mortensen, D.G., B.P. Snyder, and E.O. Salo. 1976. An analysis of the literature on the effects of dredging on juvenile salmonids. University of Washington. Fisheries Research Institute, FRI-UW-7605.

National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS). 2005. Endangered Species Act – Section 7 Consultation and Magnuson-Stevens Act Essential Fish Habitat Consultation Biological Opinion. City of Seattle, Seattle Aquarium, Pier 59 Pile Superstructure Maintenance, Fifth Field HUC 1711001904, Puget Sound/East Passage. February 25, 2005.

NMFS. 1999. Essential Fish Habitat consultation guidance. National Marine Fisheries Service, Office of Habitat Conservation.

NMFS. 2006. Listing Endangered and Threatened Species and Designating Critical Habitat: 12-month Finding on Petition to List Puget Sound Steelhead as an Endangered or Threatened Species under the Endangered Species Act. National Marine Fisheries Service, Proposed Rule, Petition Finding. March 29, 2006. Federal Register 71(60) 15666-15680.

Nelson, T., G. Ruggerone, H. Kim, R. Schaefer, and M. Boles. 2004. Draft - Juvenile Chinook migration, growth and habitat use in the Lower Green River, Duwamish River and Nearshore of Elliott Bay, 2001-2003. Prepared by King County Department of Natural Resources and Parks, Water and Land Resources Division.

Newcombe, C.P. and D.D. MacDonald. 1991. Effects of Suspended Sediment on Aquatic Ecosytems. North American Journal of Fisheries Management. 11:72-82.

Nightingale, Barbara and Charles Simenstad. 2001. *Overwater Structures: Marine Issues*. White paper prepared by the University of Washington School of Aquatic and Fishery Sciences Wetland Ecosystem Team, Seattle, WA.

Noggle, C.C. 1978. *Behavioral, Physiological and Lethal Effects of Suspended Sediment on Juvenile Salmonids.* Master's thesis. University of Washington, Seattle, Washington.

Olson, A.M., S. D. Visconty, and C. M. Sweeny. 1996. A new approach to modeling the shade cast by overwater structures. Abstract for the Pacific Estuarine Research Society 19th Annual Meeting. Washington Department of Ecology, Olympia, WA.

Osborne, R., J. Calambokidis, and E.M. Dorsey. 1988. A guide to marine mammals of greater Puget Sound. Island Publishers, Anacortes, Washington. 191 pp.

Parametrix. 2004. Fisheries, Wildlife, and Habitat Discipline Report. Appendix R of the Draft Environmental Impact Statement for SR 99 Alaskan Way Viaduct and Seawall Replacement Project. Prepared for the Washington State Department of Transportation, the City of Seattle, and the Federal Transit Authority. March 2004.

Pentec Environmental (Pentec). 1997. Movement of juvenile salmon through industrialized areas of Everett Harbor, Pentec Environmental, Edmonds, WA.

Penttila D. and D. Doty. 1990. Results of 1989 eelgrass shading studies in Puget Sound. Progress Report. Marine Fish Habitat Investigation Division, Washington Department of Fish and Wildlife. Olympia, Washington.

Poston, T. 2001. Treated Wood Issues Associated with Overwater Structures in Marine and Freshwater Environments. White Paper prepared for Washington Department of Fish and Wildlife. April 5, 2001.

Redding, M. J., C.B. Schreck, and F.H. Everest. 1987. *Physiological Effects on Coho Salmon and Steelhead of Exposure to Suspended Solids.* Trans. of the Am. Fish. Soc. 116:737-744.

Ridolfi Inc. 2004. Biological Assessment for the City of Seattle – Seattle Aquarium, Pier 59 Pile Superstructure Maintenance. Prepared for Seattle Parks and Recreation. April 2004.

Roni, P.R. and L.A . Weitkamp. 1996. *Environmental Monitoring of the Manchester Naval Fuel Pier Replacement, Puget Sound, Washington, 1991-1994.* Report for the Department of the Navy and the Coastal Zone and Estuarine Studies Division, Northwest Fisheries Science Center, National Marine Fisheries Service. January 1996.

Ruggerone, G.T. and E.C. Volk. 2004. Draft - Residence time and growth of natural and hatchery Chinook salmon in the Duwamish Estuary and Elliott Bay, Washington, based on otolith chemical and structural attributes. Prepared for U.S. Army Corps of Engineers and Port of Seattle. September 2004.

Seattle Department of Planning and Development (Seattle DPD). 2006. Draft Seattle's Central Waterfront Concept Plan. Prepared by the Seattle Department of Planning and Development. February 1, 2006.

Servizi, J.A. 1988. *Sublethal Effects of Dredged Sediments on Juvenile Salmon*. Pages 57-63 in C.A. Simenstad, ed., Effects of Dredging on Anadromous Pacific Coast fishes. University of Washington, Seattle, Washington.

Servizi, J.A. and D.W. Martens. 1987. *Some Effects of Suspended Fraser River Sediments on Sockeye Salmon (Oncorhynchus nerka)*. Page 254-264 in H.D. Smith, L. Margolis, and C.C. Wood, eds. Sockeye Salmon (*Oncorhynchus nerka*) Population Biology and Future Management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Servizi, J.A., and D.W. Martens. 1992. *Sublethal Responses of Coho Salmon (Oncorhynchus kisutch) to Suspended Sediments.* Can. J. Fish. Aquat. Sci. 49:1389-1395.

Shaw, E.A. and J.S. Richardson. 2001. Direct and indirect effects of sediment pulse duration on stream invertebrate assemblages and rainbow trout (*Oncorhynchus mykiss*) growth and survival. Can. J. Fish. Aquat. Sci. 58:2213-2221.

Simenstad, C.A. 1988. Summary and conclusions from workshop and working group discussions. Pages 144-152 in C.A. Simenstad, ed. Effects of dredging on anadromous Pacific coast fishes. University of Washington, Seattle, Washington.

Simenstad, C.A. and R.M. Thom. 1996. Functional equivalency trajectories of the restored Gog-Le-Hi-Te estuarine wetland. *Ecol. Appl.* 6:38-56.

Taylor Associates. 1995. Aquatic Environment Technical Report. Redevelopment of the Seattle Aquarium and Waterfront Park. Prepared for Seattle Department of Parks and Recreation. November 30, 1995.

Thom, R.M., C.A. Simenstad, J.R. Cordell, and E.O. Salo. 1986. Early Successional Development of a Benthic-Epibenthic Community at a Newly Constructed Beach in Slip 1, C Commencement Bay, Washington: Initial Observations 1985. Final report to Port of Tacoma, Tacoma, Washington. From Fisheries Research Institute, University of Washington, Seattle, Washington, Technical Report FRI-UW-86-3. 42p.

Thom, R.M., G.D. Williams, and seven authors. 2006. Impacts of Ferry Terminals and Ferry Operations on Juvenile Salmon Migrating Along Puget Sound Shorelines: Current Level of Knowledge. Prepared for the Washington State Department of Transportation. March 2006.

Toft, J. and J. Cordell. 2006. Olympic Sculpture Park: Results from Pre-construction Biological Monitoring of Shoreline Habitats. Prepared for Seattle Public Utilities, City of Seattle. Prepared by the Wetland Ecosystem Team of the University of Washington. Report Number SAFS-UW-0601. April 2006.

TRA Planning Services and Vicki Morris Consulting. 1995. Seattle Aquarium Master Plan for Expansion Draft Programmatic Environmental Impact Statement. Preliminary Draft. August 25, 1995.

Warner, E.J. and R.L. Fritz. 1995. The Distribution and Growth of Green River Chinook Salmon (Oncorhynchus tshawytscha) and Chum Salmon (Oncorhynchus keta) Outmigrants in the Duwamish Estuary as a Function of Water Quality and Substrate. Muckleshoot Indian Tribe Fisheries Department. Auburn, Washington.

Washington Department of Fish and Wildlife (WDFW). 2005. *Priority Habitat and Species Map*. Olympia, WA.

Water Resource Inventory Area 9 Steering Committee (W9SC). 2005. *Making Our Watershed Fit for a King: Preview Draft Habitat Plan*. Prepared for the Green/Duwamish and Central Puget Sound Watershed Water Resource Inventory Area 9. August 2005.

Weitkamp, D. E. 1991. Epibenthic zooplankton production and fish distribution at selected pier apron and adjacent non-apron sites in Commencement Bay, WA, Report to Port of Tacoma.

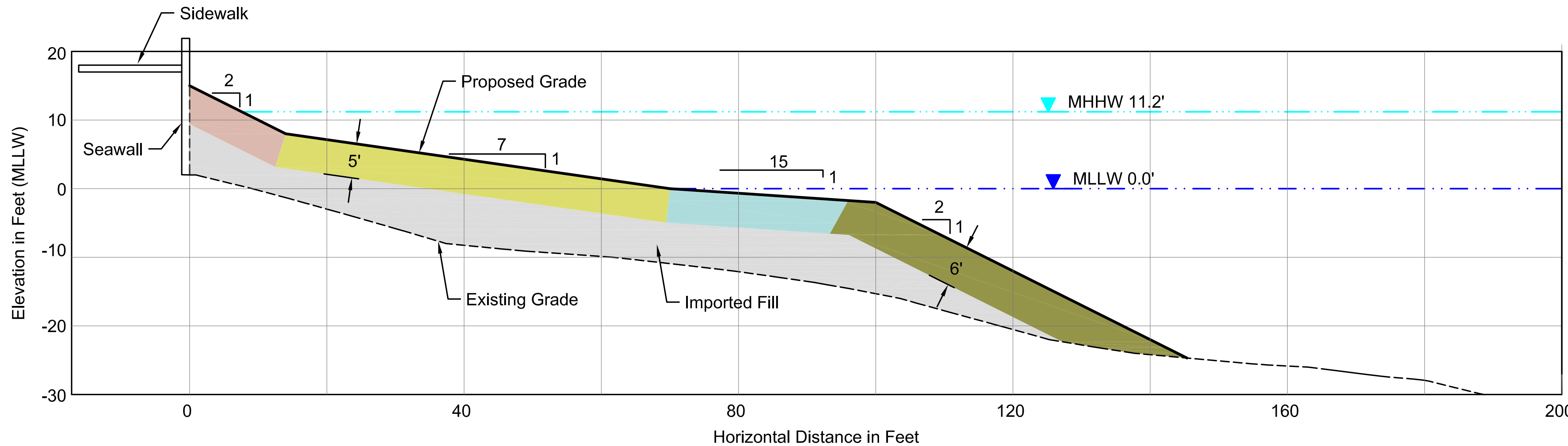
Weitkamp, D.E. 2003. Seattle Seawall Underwater Survey. A dive video record of biota and substrate along Seattle Seawall. Parametrix, Seattle, WA.

Weitkamp, D.E. and T. Schadt. 1982. Juvenile chum and Chinook salmon behavior at Terminal 91, Seattle, Washington. Prepared for Port of Seattle by Parametrix.

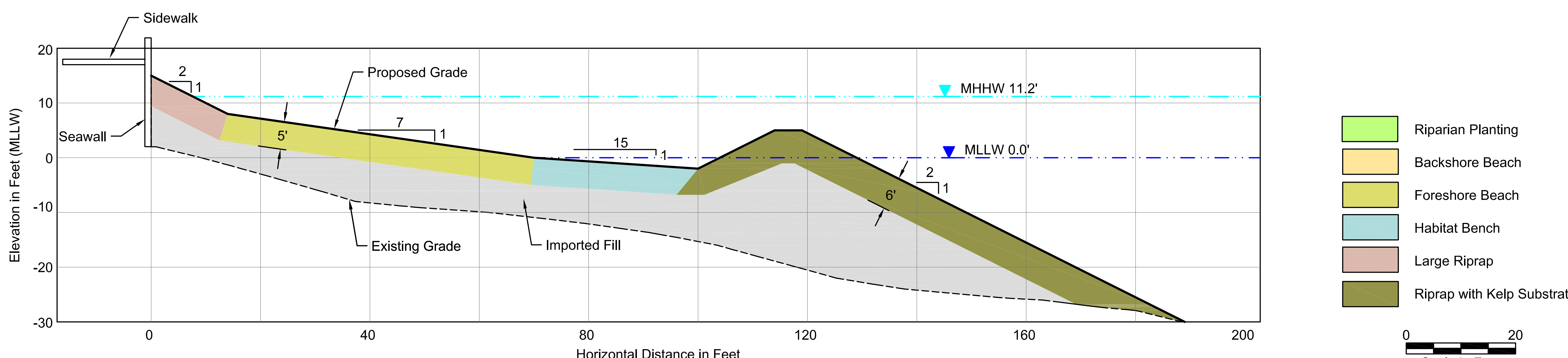
Wilbur, D.H. and D.G. Clarke. 2001. Biological Effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. North American Journal of Fisheries Management. 21:855-875.

Williams, G.D., R.M. Thom, J.E. Starkes, and 14 authors. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9). J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, WA.

FIGURES



Foreshore Beach with Habitat Bench

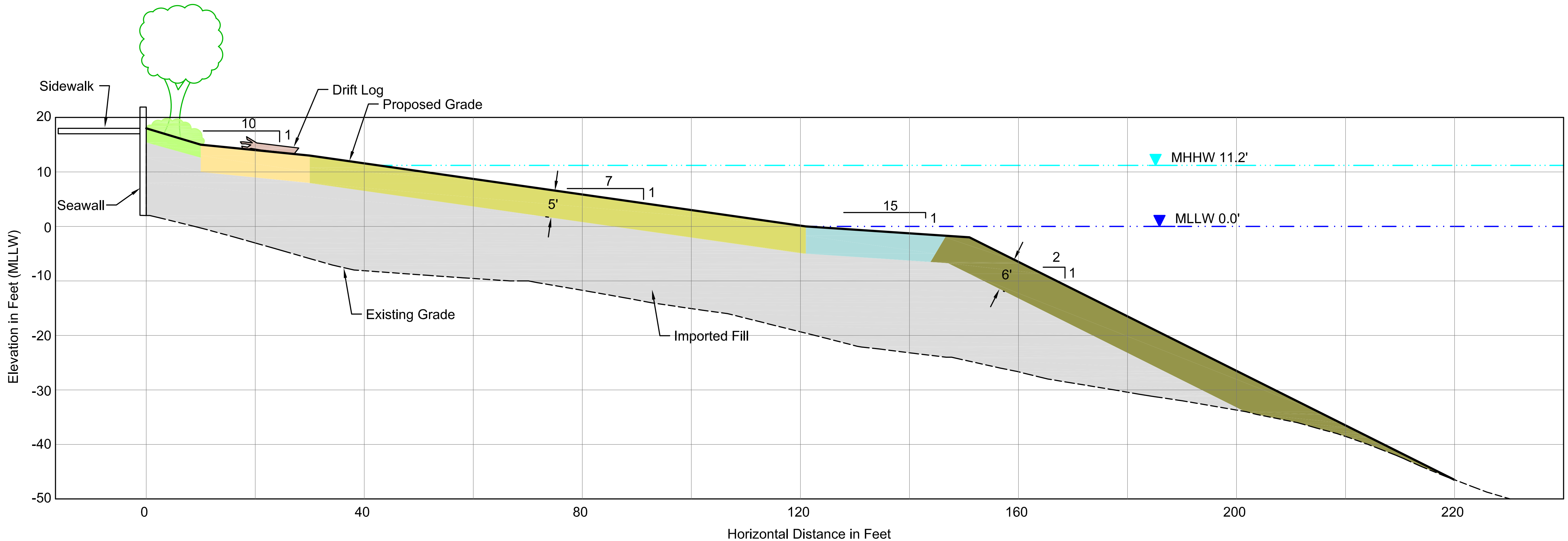


Foreshore Beach with Habitat Bench & Rock Wave Attenuator

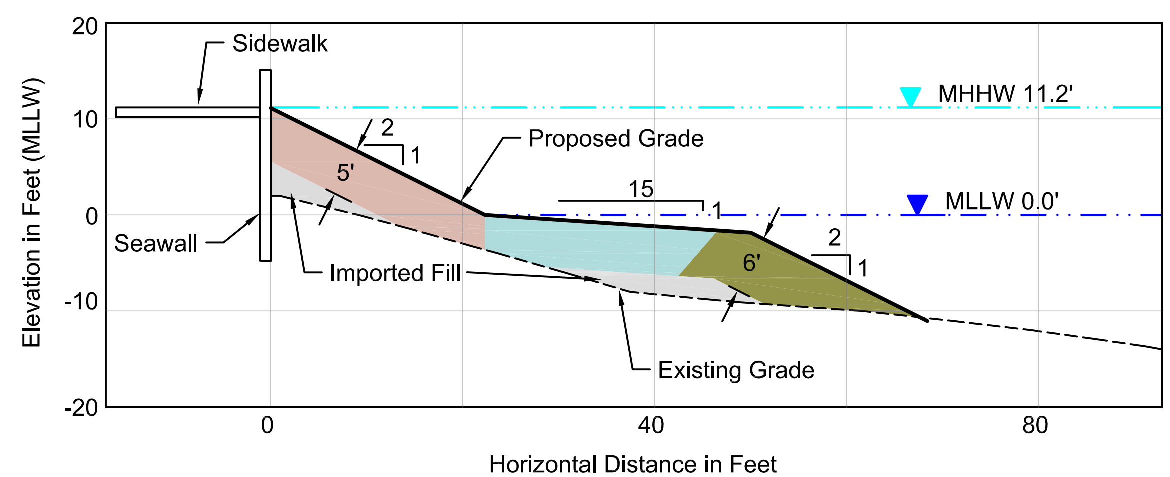
Apr 14, 2006 2:31pm cdavidson K:\Jobs\060302-Seattle Central Waterfront\06030201\06030201-013.dwg FIG 1a

ANCHOR ENVIRONMENTAL, L.L.C.

Figure 1a
Cross-Sections of Proposed Nearshore Habitat Improvement
Central Waterfront
Seattle, Washington



Backshore Beach with Habitat Bench



Habitat Bench

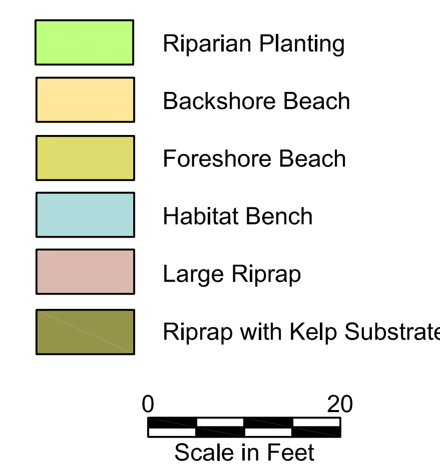


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Figure 1b
Cross-Sections of Proposed Nearshore Habitat Improvement
Central Waterfrtont
Seattle, Washington

Rebuild/Preservation Alternative

The Rebuild/Preservation Alternative would rebuild Piers 62/63 as a similar structure in the same location but set away from the shoreline. Waterfront Park would be renovated in Phase 1, but then would be demolished along with Pier 60, as part of the Seattle Aquarium's expansion. Habitat would be enhanced along the shoreline, except underneath the expanded Seattle Aquarium, including an accessible beach at the current Waterfront Park.

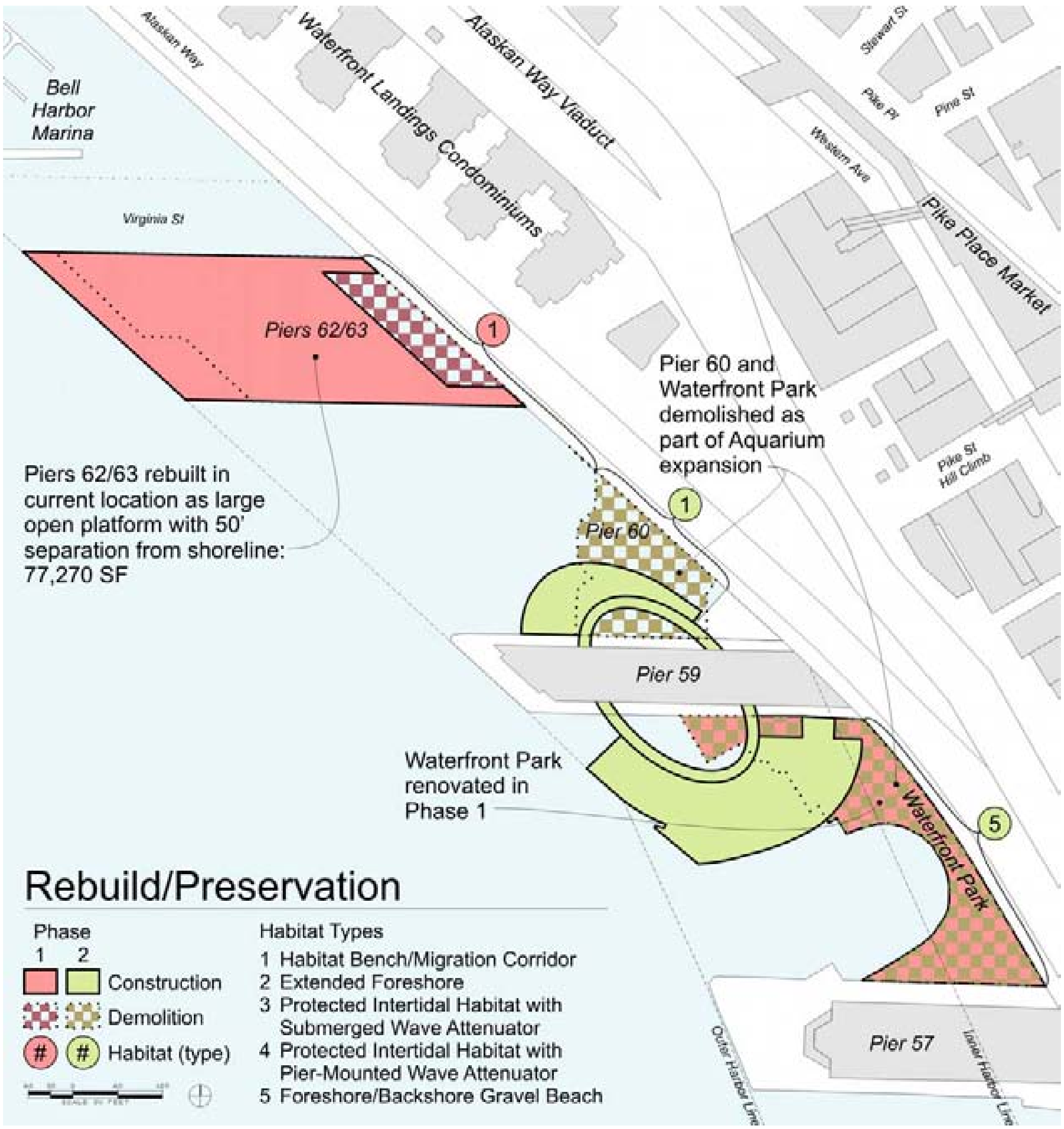

Figure 2. Rebuild/Preservation Alternative

Aqua Link Alternative

The Aqua Link Alternative would rebuild Piers 62/63 as a smaller structure closer to the Aquarium. It would also build a new deck connecting Piers 59 and 57. Waterfront Park and Pier 60 would be demolished as part of the Seattle Aquarium expansion. Habitat would be enhanced along the shoreline, except underneath the expanded Seattle Aquarium, including an accessible beach from the northern edge of Pier 60 to the southern edge of the submerged Virginia Street right-of-way.

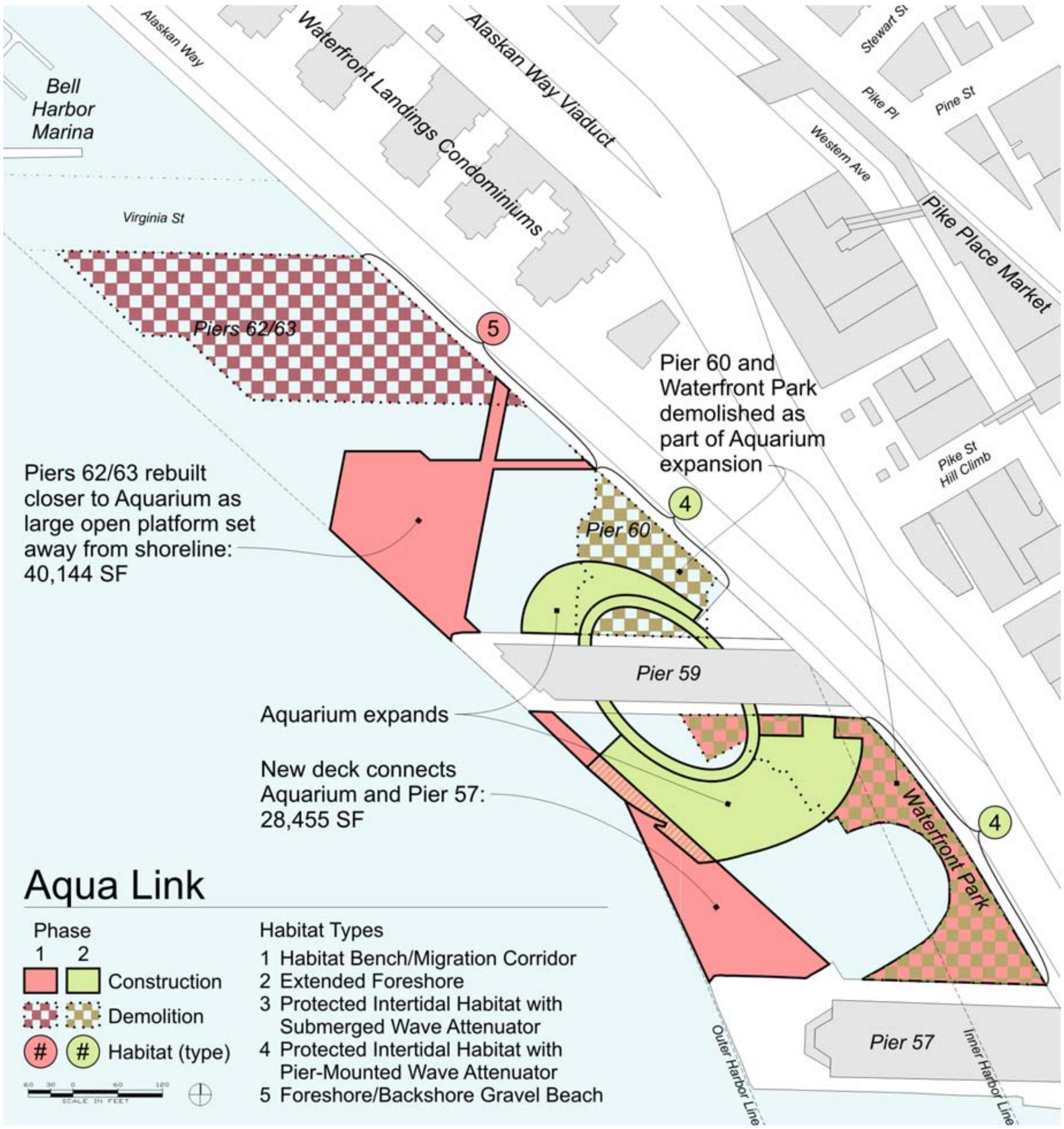

Figure 3. Aqua Link Alternative

Connector Alternative

The Connector Alternative would rebuild Piers 62/63 as a similar structure in the same location but set away from the shoreline. It would also build a slender footbridge and deck connecting to the Seattle Aquarium. Waterfront Park and Pier 60 would be demolished as part of the Seattle Aquarium expansion. Habitat would be enhanced along the shoreline, except underneath the expanded Seattle Aquarium, including an accessible beach between the new pier and the northern edge of Pier 60.

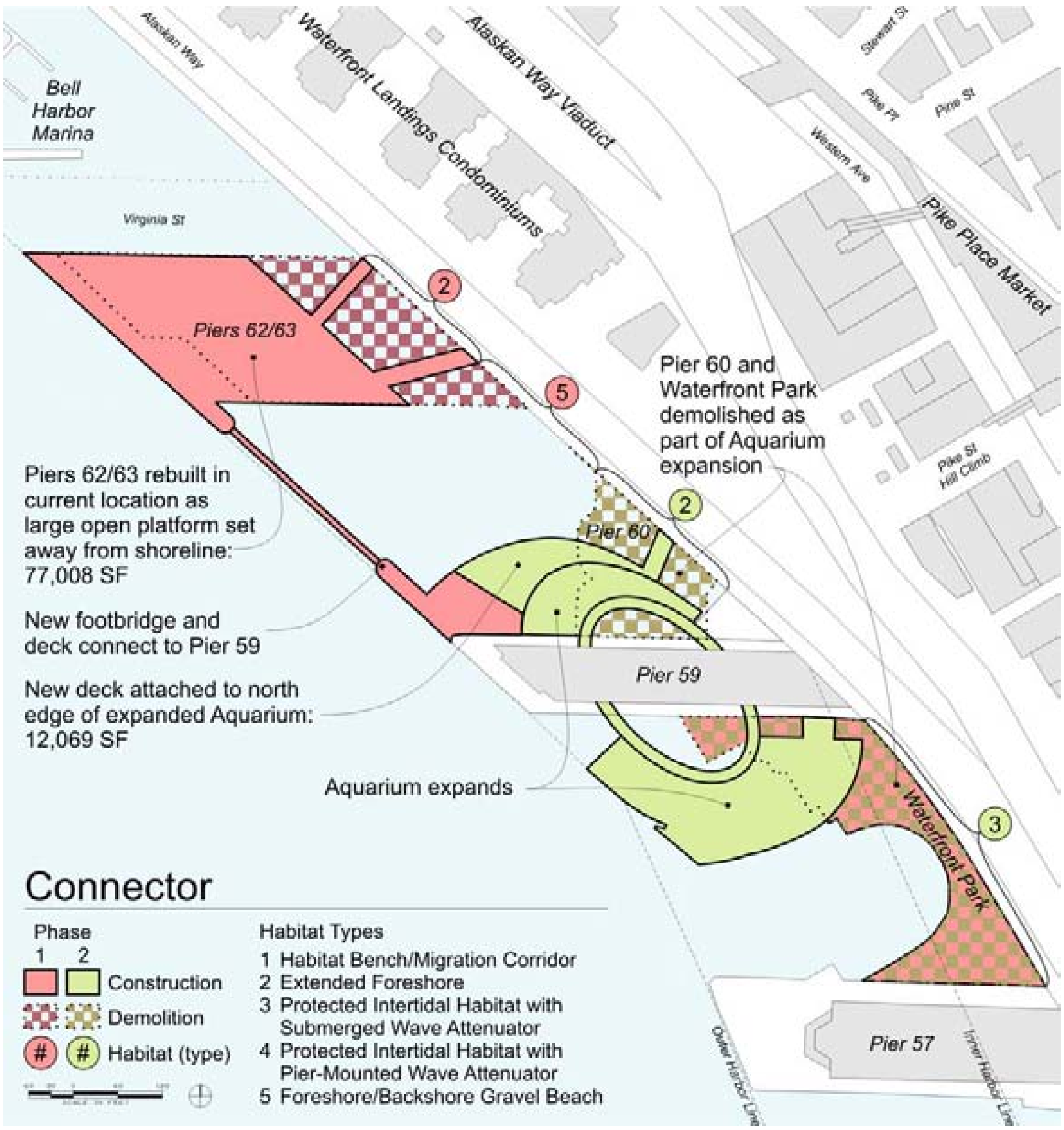

Figure 4. Connector Alternative

Multi-Purpose Pier Alternative

The Multi-Purpose Pier Alternative would rebuild Piers 62/63 as a large open platform abutting an expanded Seattle Aquarium and set away from the shoreline. Waterfront Park and Pier 60 would be demolished as part of the Seattle Aquarium expansion. Habitat would be enhanced along the shoreline, except underneath the expanded Seattle Aquarium, including an accessible beach at the current Waterfront Park.

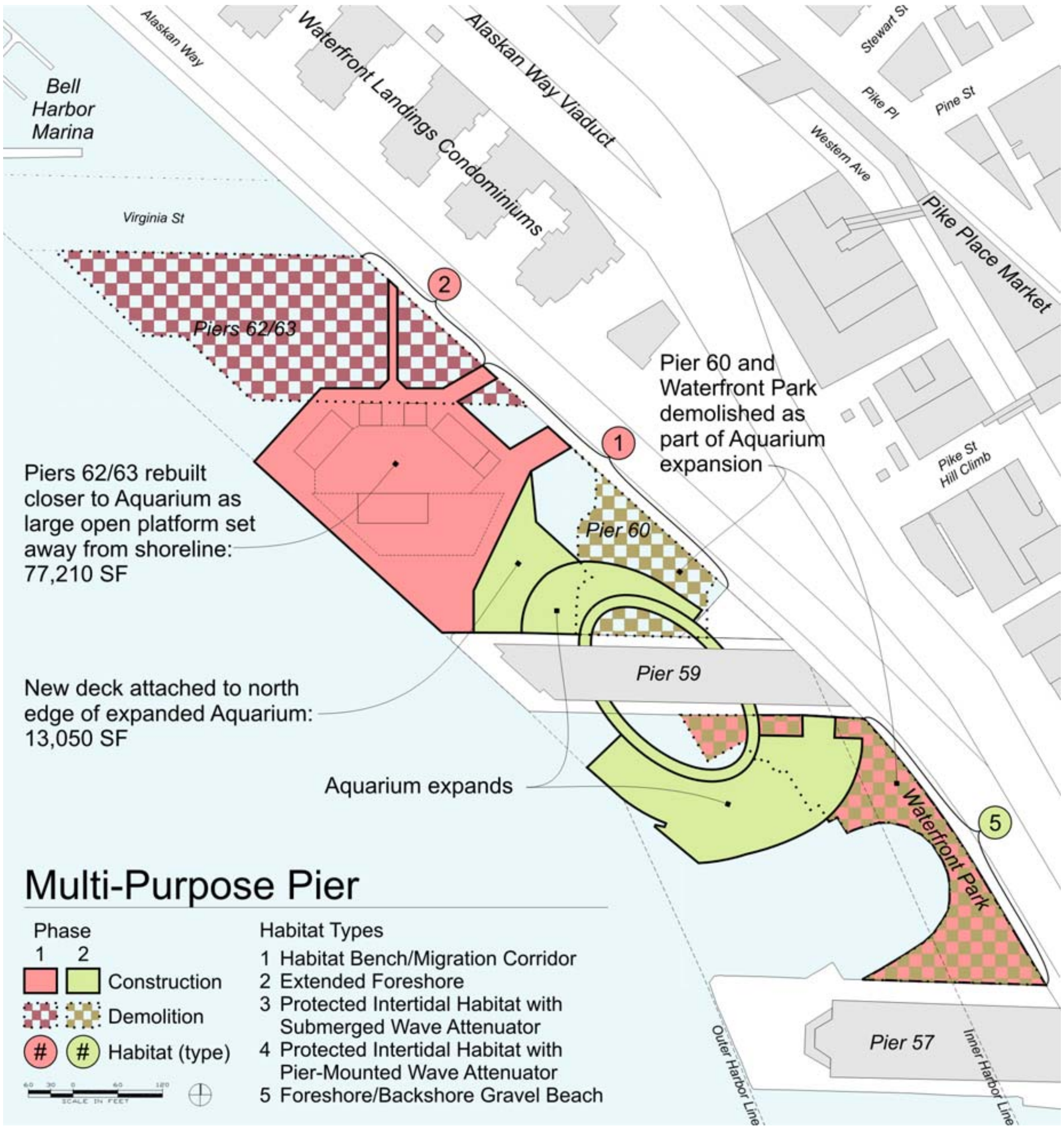

Figure 5. Multi-Purpose Pier Alternative

Apr 17, 2006 2:34pm cdavidson K:\Jobs\060302-Seattle Central Waterfront\06030201\06030201-008.dwg Existing

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Figure 6
Existing Conditons in Project Area
Central Waterfront
Seattle, Washington